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Initial Closure Planning for the Blue Grass and Pueblo Chemical Agent Destruction Pilot Plants: Letter Report (2020)

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April 6, 2020

Mr. Michael Abaie
Program Executive Officer
Assembled Chemical Weapons Alternatives
8198 Blackhawk Road, Edgewood Area
Aberdeen, MD 21010-5424

Dear Mr. Abaie:

You requested that the National Academies of Sciences, Engineering, and Medicine produce a letter report addressing initial closure planning for the Blue Grass and Pueblo Chemical Agent Destruction Pilot Plants (BGCAPP and PCAPP). In the course of conducting its work, the committee was to (1) review National Academies reports that directly addressed or touched on the closure of previous chemical demilitarization facilities and (2) to receive actual historical closure information from the Program Executive Office for Assembled Chemical Weapons Alternatives (PEO ACWA). The committee members were then to apply their experience and expert judgment to make findings and recommendations regarding planning for the closure of BGCAPP and PCAPP.

This study was initiated on June 27, 2019. The National Academies selected committee members with extensive past experience in chemistry, chemical engineering, environmental regulation, environmental safety, hazardous materials handling and disposal, industrial engineering, industrial hygiene, and occupational safety and health. The Committee on Initial Closure Planning for the Blue Grass and Pueblo Chemical Agent Destruction Pilot Plants was established to accomplish this task. A committee meeting was on August 13-16, 2019. At this meeting, the committee engaged in-depth with Ms. Amy Dean, senior project engineer, U.S. Army Futures Command, who has participated in several previous closure efforts, and Mr. Jeffrey Brubaker, technical advisor to the site project manager, BGCAPP, who managed the closure of the Newport Chemical Agent Disposal Facility (NECDF). The committee also engaged in several rounds of questions to PEO ACWA and received historical closure information regarding the Johnston Atoll Chemical Agent Disposal System (JACADS), the Anniston Chemical Agent Disposal Facility (ANCDF), the Pine Bluff Chemical Agent Disposal Facility (PBCDF), and the Umatilla Chemical Agent Disposal Facility (UMCDF).

Attachment A contains the committee roster and biographies. Attachment B contains the references. Attachment C contains a list of acronyms used in this report. Attachment D acknowledges the reviewers. Attachment E is a listing of relevant state-specific hazardous waste codes under applicable regulations.

Sincerely,



Timothy J. Shepodd, Chair
Committee on Initial Closure Planning
for the Blue Grass and Pueblo Chemical
Agent Destruction Pilot Plants

Attachments

- A Roster and Biographical Information
- B References
- C Acronyms
- D Acknowledgment of Reviewers
- E State-Specific Lists of Chemical Agents and Related Materials as Hazardous Wastes

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Initial Closure Planning for the Blue Grass and Pueblo Chemical Agent Destruction Pilot Plants

SUMMARY OF MAIN REPORT TOPICS AND THEMES

This report addresses various aspects of closing PCAPP and BGCAPP. The committee was tasked to review documents related to the closure of legacy chemical demilitarization plants and use their expert judgment to identify key areas and issues that should be considered when planning for closing PCAPP and BGCAPP. This report presents those key issues in three broad categories: decontamination and hazardous waste; safety and industrial hygiene; and environmental safety, regulations, and permitting.

Decontamination and Hazardous Wastes

This section addresses closure decontamination at PCAPP and BGCAPP. A large quantity of wastes will be generated and characterizing and disposing of these wastes has the potential to slow the rate of the overall closure process. The committee has concerns that the volumes of wastes needing characterization and disposition might exceed both laboratory characterization capacity and physical storage space, possibly slowing closure. In addition, the unventilated monitoring test, which is being critically relied upon to clear complex machinery and areas, is time consuming and labor intensive. Consequently, the committee believes that the implementation of the unventilated monitoring test and its effects on the overall closure rate needs to be carefully evaluated. This section also addresses different decontamination methods—thermal, chemical, and physical. In general, the committee believes that the existing thermal units at PCAPP and BCAPP might be used more extensively to aid in closure decontamination. One additional concern is that past experience with the decontamination of static detonation chambers (SDCs) indicates that there may be unanticipated challenges, contributing to the overall time required for closure.

Worker Safety and Industrial Hygiene

This section discusses safety best practices and encourages PEO ACWA to maintain its current excellent safety program when it transitions into closure. The committee discusses the change in the nature of tasks moving from operations to closure, moving from regular, repeating tasks in a stable environment to new and sometimes unique tasks in a changing environment. The committee also addresses the fact that, with the closure of PCAPP and BGCAPP, the entire chemical stockpile disposal program is ending and that this could create challenges retaining experienced workers through the end of closure. The committee also discusses non-agent hazards that workers could encounter as a way to encourage PEO ACWA to maintain an awareness of these new hazards. Finally, the committee addresses ergonomics hazards and possible mitigations.

Environmental Safety, Regulations, and Permitting

This section reviews the regulatory regimes that will govern the closure of PCAPP and BGCAPP. In general, just as plant operations are governed by hazardous waste regulations and permits, closure will be, too. The committee notes that early and frequent engagement with regulators on closure plans can help ease and speed the closure process. It highlights that many closure-related wastes may be classified as hazardous wastes based on the presence of chemical agents or other characteristics, although certain exemptions may apply, such as for debris that has been decontaminated or scrap metal that is recycled.

For wastes that are hazardous, the committee discusses key requirements for treatment and storage. The committee reviews regulations outside the hazardous waste arena that may also apply during closure, such as requirements under Toxic Substances Control Act (TSCA) that may be triggered by treating the shipping and firing tubes (SFTs) of M55 rockets, which contain polychlorinated biphenyls (PCBs), at onsite BGCAPP.

GUIDE TO THE REPORT

This report begins with an Introduction (pp. 4-10) that lays out the basis for this study and presents the statement of task, discusses legacy chemical demilitarization facilities, provides a brief description of the PCAPP and BGCAPP processes and equipment significant to this report, gives the regulatory framework, reports the status of these plants, and briefly discusses the challenges inherent in closing PCAPP and BGCAPP. The Introduction also presents the scope of the report—what is and is not discussed—and presents the major sources of information used in authoring this report.

The report next discusses Decontaminating and Hazardous Wastes (pp. 10-17). This section presents a general overview of what closing PCAPP and BGCAPP will involve. It then discusses the quantities and characteristics of the anticipated waste streams, moves on to contaminated waste materials and decontamination strategies (which are broken down into thermal, chemical, and physical categories), and discusses potential issues with closing the SDCs. Finally the section discusses the challenges in characterizing closure wastes.

The Worker Safety and Industrial Hygiene section (pp. 17-25) discusses assumptions and best practices in occupational safety and industrial hygiene. It then moves on to discuss safety considerations specific to closure operations using experience from the closures of legacy facilities and looking forward to the closures of PCAPP and BGCAPP. The section closes with a discussion of the agent, non-agent, and ergonomics hazards that the committee anticipates will be present during closure.

The Environmental Protection, Regulations, and Permitting section (pp. 25-32) discusses the regulatory frameworks that govern operations and will govern the closures of PCAPP and BGCAPP. It specifically addresses closure requirements and the classification of closure wastes. Finally, the section discusses state-specific requirements for managing closure wastes and the requirements of the Land Disposal Restrictions (LDRs) and TSCA.

The report's Conclusion (pp. 33-36) presents the committee's final thoughts and lists the report recommendations. Attachment A provides the committee roster and biographical information, Attachment B contains the report references, Attachment C presents an acronym list, Attachment D is the acknowledgement of the reviewers, and Attachment E presents a full listing of the Colorado and Kentucky state-specific hazardous waste codes that pertain to PCAPP and BGCAPP.

INTRODUCTION

The PEO ACWA is building, operating, and will eventually close two plants to dispose of the last of the U.S. chemical weapons stockpile. The first is PCAPP operating on the Pueblo Chemical Depot (PCD) in Colorado. The second is BGCAPP, operating outside Lexington, Kentucky as a tenant on the Blue Grass Army Depot (BGAD). These plants use chemical neutralization to destroy chemical agent. Both PCAPP and BGCAPP have extensive secondary processing operations whereby the neutralized agent, called hydrolysate, will be further treated. At a minimum, the secondary treatment subsystems add complexity to the closure process. Given that agent operations at these plants must be completed by December 31, 2023, to meet a congressional mandate, neither PCAPP nor BGCAPP will have long operational lives. Accordingly, PEO ACWA has determined that it is time to start initial planning for

closing these plants in accordance with their governing Resource Conservation and Recovery Act (RCRA) permits and has engaged the National Academies of Sciences, Engineering, and Medicine to assist with this effort.

Statement of Task

Drawing on previous National Academies reports that addressed the closure of chemical agent disposal facilities, and on information that will be provided by PEO ACWA, the committee will:

- Identify lessons learned, significant risks, or issues that arose during the closure of Chemical Materials Agency (CMA)¹ chemical agent disposal facilities that would be applicable to the closure of PCAPP and BGCAPP, including the treatment of hydrolysates and liquid secondary wastes. Aspects of closure to be covered will include, but not necessarily be limited to, the deconstruction of large and complex industrial facilities, decontamination, environmental permitting and safety, the handling and disposal of hazardous materials, and occupational safety and health.
- Make findings and recommendations to assist PEO ACWA in defining best practices and approaches for the closure of PCAPP and BGCAPP.

To accomplish the statement of task, a committee was appointed that includes expertise in chemistry, chemical engineering, environmental regulation, environmental safety, the handling and disposal of hazardous materials, industrial engineering, industrial hygiene, and occupational safety and health.

Legacy Chemical Demilitarization Facilities

Under the management of the CMA, seven legacy facilities have successfully destroyed the stockpiles of chemical agent and munitions stored at their locations, representing 90 percent of the total U.S. stockpile. Five of these facilities used incineration to destroy chemical agent. They were known as the baseline sites:

- Anniston Chemical Agent Disposal Facility (ANCDF), Alabama;
- Johnston Atoll Chemical Agent Disposal System (JACADS), Johnston Island;
- Pine Bluff Chemical Agent Disposal Facility (PBCDF), Arkansas;
- Tooele Chemical Agent Disposal Facility (TOCDF), Utah; and
- Umatilla Chemical Agent Disposal Facility (UMCDF), Oregon.

Two facilities used chemical neutralization, or hydrolysis, to eliminate their stockpiles of bulk agent:

- Aberdeen Chemical Agent Disposal Facility (ABCDF), Maryland; and
- Newport Chemical Agent Disposal Facility (NECDF), Indiana.

Neither of these two facilities processed their hydrolysate onsite. Rather, they shipped their hydrolysate, a hazardous waste, directly to permitted treatment, storage, and disposal facilities (TSDFs). Secondary

¹ In July, 2012, after the completion of operations at the seven legacy chemical demilitarization facilities, the Chemical Materials Agency was redesignated from being a major subordinate command to a Separate Reporting Activity under the Army Materiel Command. With this change it was renamed the Chemical Materials Activity. Both organizations, the legacy one and the current one, are known as CMA.

processing of chemical agent hydrolysate was required to comply with the Chemical Weapons Convention (CWC). Table 1 shows the years of operation and years of closure for each of these legacy sites.

TABLE 1 Operating and Closure Dates for Legacy Chemical Demilitarization Plants, Ordered by Closure Years

Plant	Years of Operation ^a	Year Closure Completed ^b
ABCDF	2003-2006	2007
JACADS	1990-2000	2009 ^c
NECDF	2005-2008	2010
PBCDF	2005-2010	2013
ANCDF	2003-2011	2014
TOCDF	1996-2012	2014
UMCDF	2004-2011	2015

^a CMA (2012).

^b Morris (2015).

^c Actual plant demolition was completed in 2003 (see “Johnston Atoll Chemical Agent Disposal System,” https://en.wikipedia.org/wiki/Johnston_Atoll_Chemical_Agent_Disposal_System), but because there were several tenants on Johnston Atoll and several distinct federal agencies involved, formal closure took some time after that point.

NOTE: ABCDF, Aberdeen Chemical Agent Disposal Facility ; ANCDF, Anniston Chemical Agent Disposal Facility; JACADS, Johnston Atoll Chemical Agent Disposal System; NECDF, Newport Chemical Agent Disposal Facility; PBCDF, Pine Bluff Chemical Agent Disposal Facility; TODCF, Tooele Chemical Agent Disposal Facility; UMCDF, Umatilla Chemical Agent Disposal Facility.

PCAPP and BGCAPP Design and Operation

The PCAPP Main Plant Process

At PCAPP, the main plant uses an automated processing line to remove energetics and drain mustard agent from munitions, and then uses hot water to neutralize the mustard, producing hydrolysate. Theoretically, pure mustard hydrolyzes to thiodiglycol. The impure, perhaps partially gelled, mustard agent found in legacy munitions produces hydrolysate with a more complex mixture of organics. After the hydrolysate has been analyzed and cleared for further processing by the facility laboratory, PCAPP processes the hydrolysate through an on-site bioremediation plant, where biomass from local sewage cultures consumes the thiodiglycol and other organics to achieve CWC-compliant agent destruction. The bioremediation plant is large, and complex, and contains hazardous materials. Even though the bioremediation plant will not contain mustard, this additional plant will increase the complexity of the demolition process.

The BGCAPP Main Plant Process

The BGCAPP main plant began operations in January 2020. It uses hot aqueous sodium hydroxide to chemically neutralize the nerve agents GB (Sarin) and VX that are contained in projectiles. The resulting hydrolysate will be processed through a supercritical water oxidation (SCWO) system to achieve CWC-compliant destruction, producing inorganic salts and water. The SCWO system is an additional chemical processing plant and introduces additional complexity to closure. The SCWO secondary treatment is a complex, operation requiring the regular replacement of the reactor liners and

thermowells. PEO ACWA has committed to a 6-month trial of the SCWO system. The results of the trial will be evaluated to determine whether the SCWO is operating at a capacity that will support main plant operations.

SDCs

Some munitions have physical damage that does not allow them to be processed properly through the main PCAPP and BGCAPP plants. Additionally, some munitions have leaked and been overpacked, or have agent fill that has partially solidified. These munitions will be disposed of thermally in SDCs at both PCAPP and BGCAPP.² The scrap resulting from treatment in SDCs is expected to be agent-free and suitable for recycling. At PCAPP, scrap from each SDC unit will be monitored at first to demonstrate that the SDC is destroying all agent. Once this has been demonstrated, the scrap will be deemed agent-free based on process knowledge.³ At BGCAPP, scrap is deemed to be agent-free based on process knowledge.⁴ PCAPP is installing three SDCs; BGCAPP currently has one SDC and a second will be installed in 2021.⁵

Additionally, at PCAPP and BGCAPP certain munitions types will be disposed of entirely by the SDCs. All 4.2-inch mortars at PCAPP and all mustard munitions at BGCAPP will be processed in SDCs. In addition, the GB- and VX-filled rockets in the BGCAPP stockpile will be processed by separating the agent-filled warheads from the propellant-filled rocket motors. The warheads will be punched, drained, placed into a metal canister, and processed through the BGCAPP SDCs. The rocket motors, if uncontaminated, will be processed at an offsite TSDF.

Other Thermal Treatment Subsystems

Both PCAPP and BGCAPP have other thermal subsystems for agent decontamination to meet permit-specified standards, including the following:

- The munition treatment unit (MTU) at PCAPP, for thermal decontamination of drained and washed munition bodies;
- The supplemental decontamination unit at PCAPP, to decontaminate secondary wastes to meet a specified airborne exposure limit; and
- The metal parts treater (MPT) at BGCAPP, for the thermal decontamination of drained munition bodies, metal parts, and dunnage, both in operations and to assist with plant closure.

² For more information about Static Detonation Chamber (SDCs), see Program Executive Office, Assembled Chemical Weapons Alternatives (PEO ACWA), “Static Detonation Chamber,” <https://www.peoacwa.army.mil/bgcapp/bgcapp-destruction-technologies/static-detonation-chamber/>, accessed January 23, 2020.

³ Conversation between Sean Smith, Field Operations Directorate (PCAPP), PEO ACWA, and James Myska, study director, National Academies of Sciences, Engineering, and Medicine, on January 10, 2020.

⁴ E-mail communication between Jeffrey L. Brubaker, technical advisor to the site project manager, Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP), and James Myska, study director, National Academies, on January 13, 2020.

⁵ E-mail communication between Jeffrey L. Brubaker, technical advisor to the site project manager, BGCAPP, and James Myska, study director, National Academies, on January 8, 2020.

Regulatory Framework

All of the key PCAPP and BGCAPP operations are conducted under state-specific hazardous waste permits and regulations. Closure of such operations will also be governed by the state-specific hazardous waste permits and regulations. Other regulatory regimes may also be applicable to certain operations and closure activities, such as the Clean Air Act (CAA), the Clean Water Act, and the Toxic Substances Control Act (TSCA).

PCAPP and BGCAPP Status

As of February 21, 2020, PCAPP has disposed of 1,297.8 U.S. tons of mustard agent, or 49.66 percent of the mustard stockpile stored at PCD.⁶ As of February 21, 2020, BGCAPP has disposed of 18.9 U.S. tons of mustard agent, or 3.61 percent of the chemical agent stockpile stored at BGAD.⁷

Closing PCAPP and BGCAPP

Closing PCAPP and BGCAPP, while conceptually similar to legacy facility closure operations, will be more complex. There are considerations unique to closing PCAPP and BGCAPP that will need to be carefully considered. The closure plans for PCAPP and BGCAPP have not yet been drafted as they still have some time until they complete operations. Therefore, there is no concrete information about what is and is not planned for closing these plants and no hard information on specifically what kinds and quantities of wastes there will be during closure. PEO ACWA is now beginning to think about closure and this report is part of that initial effort. As a result, this report addresses factors and topics related to closure at a general level and recommends that PEO ACWA and the plants obtain the detailed information that will be necessary to plan and conduct closure.

PCAPP and BGCAPP are large, complex structures containing a great deal of piping, robotic automation, and very large pieces of equipment. They are technically much more complex than the legacy facilities. Some of the equipment is so large that it was emplaced and the surrounding plant infrastructure subsequently built around it. The robots and associated munition handling equipment are large pieces of equipment composed of many parts. They will very likely be contaminated, and their complex structures create multiple opportunities for agent to be present in occluded spaces. Some of the large pieces of equipment may need to be disassembled. In this case, there will be additional hazards because workers in personal protective equipment (PPE) suffer from reduced dexterity and mobility. Tasks take longer in PPE because workers are subject to time limits before they must stop work and leave the environment. It will take careful planning to ensure the optimum sequencing of the various plant subsystem decontamination activities, the consideration of all hazards, and the proper training necessary to safely close these complex facilities. PCAPP and BGCAPP are tenants of larger facilities—PCD and BGAD, respectively. Coordinating the closures of PCAPP and BGCAPP with the larger activities' permitting may be useful.

As PCAPP and BGCAPP transition to closure, new and nonstandard tasks will be introduced that require additional worker training. Some parts of the plants may still be operating (e.g., the biotreatment system at PCAPP and the SCWO at BGCAPP) while closure-related tasks are being performed in other

⁶ See the PCAPP website, <https://www.peoacwa.army.mil/pcapp/>, which is periodically updated with the latest information.

⁷ See the BGCAPP website, <https://www.peoacwa.army.mil/bgcapp/>, which is periodically updated with the latest information.

areas. The evolution of worker responsibilities introduces the potential for increased risks to worker safety.

PCAPP and BGCAPP are the final chemical demilitarization sites and represent the end of the PEO ACWA program and the end of the U.S. chemical agent stockpile disposal program. The workers and management personnel associated with closure are, in the course of their duties, working themselves out of their jobs. The coincidence of closing the final plants at the end of a multidecade, multisite program requires coordination and consideration to retain the highly trained and specialized workforce through completion of the closure process. PCAPP and BGCAPP closures will start after the longest gap since a prior decommissioning (see Table 1), creating a potential knowledge gap that will need to be addressed through training. Bringing new workers in during closure would impact closure efficiency and increase the potential for safety incidents. All this work must be accomplished while protecting the safety and health of the workers, protecting the environment, and complying with the governing permit requirements.

Report Scope

In accordance with discussions with the sponsor, this report focuses on technical, engineering, workforce, safety and industrial hygiene, and environmental regulation and safety issues directly involved in closing PCAPP and BGCAPP. The report does not address broader facility issues, such as the disposition of igloos that have been used to store chemical munitions, or environmental concerns beyond those directly related to the closure of the plant systems and buildings. It does not address public concerns, economic impacts, or the like.

Sources of Information

The committee reviewed a variety of documentation in the course of its work. Chief among these were the following:

- Six prior National Academies reports that addressed or touched on closure (NRC, 2002, 2007, 2008, 2010 a,b, and 2012);
- Closure reports for ANCDF (Leidos, 2014) and PBCDF (URS, 2013);
- Closure lessons learned from JACADS;⁸
- Closure-related plans and procedures for JACADS (PMCD, 2001), PBCDF (URS, 2009), and UMCDF (URS, 2012 a,b);
- Technical information specific to PCAPP and BGCAPP;
- PCAPP and BGCAPP closure plan information (CDPHE, 2018, Attachment I, Closure Plan);⁹
- PCAPP and BGCAPP permits and a wide variety of regulatory information; and
- PEO ACWA closure guidance for PCAPP and BGCAPP.¹⁰

⁸ Briefings from the Johnston Atoll Chemical Agent Disposal System closure final integrated product team meeting on September 9-10, 2003, in San Francisco, Calif.

⁹ Roger Dickerman, operations manager, BGCAPP, “Designing for Closure: A Three-Phase Approach for Closure of the Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP) Munitions Demilitarization Building (MDB),” presentation, May 25, 2011.

¹⁰ PEO ACWA, “Guidance on Facility Closure,” memorandum, undated.

The information on the legacy sites—ANCDF, PBCDF, JACADS, and UMCDF—is representative of the closure activities across the previous chemical demilitarization sites and was used to identify pertinent lessons learned most applicable to the closure of PCAPP and BGCAPP. In some instances, specific lessons learned were identified and are referred to in this report. In other instances, however, the committee identified overarching themes from a variety of information sources to develop findings and recommendations. BGCAPP produced a designing-for-closure presentation that both captured lessons learned from three previous closure activities and presented a three-phase draft plan for closure.¹¹ The information for PCAPP and BGCAPP was used to determine how PEO ACWA was planning to close those sites. The combination of these two sets of information—legacy and forward-looking for PCAPP and BGCAPP—served as the basis for this report.

It is important to note that PEO ACWA has also had access to all of the lessons learned from the legacy sites and has actively taken them into account when planning for the construction, systemization, operation, and closure of PCAPP and BGCAPP. This is exemplified by the information in the last two items listed above. These lessons learned encompass a wide variety of topics including the appearance of agent in unexpected places and the formation of ash during SDC operations, the urgent need to keep a strong focus on safety during closure operations, and engaging state regulators early and often when planning and executing closure. These are discussed in more detail in the report text.

Finding 1. As a best practice, the PEO ACWA program has continually discovered, documented, and used lessons learned from earlier closures to guide planning for the closure of PCAPP and BGCAPP.

Recommendation 1. PEO ACWA should continue to use the lessons learned from previous closure activities to plan for the closure of PCAPP and BGCAPP. It should also use what will be learned when closing PCAPP to inform the eventual closure of BGCAPP.

Finding 2. BGCAPP and PCAPP plant closure activities are complex activities with many personnel and environmental risks that could be mitigated using various strategies.

Recommendation 2. BGCAPP and PCAPP plant staff should conduct an optimization study that balances the risks and benefits of various closure strategies, including an evaluation of interdependencies that exist in closing the various subsystems (e.g., technical requirements, labor availability, training needs, permitting issues, scheduling, physical boundaries, and environmental impacts).

DECONTAMINATION AND HAZARDOUS WASTES

The expected general closure strategy for PCAPP and BGCAPP will be to remove all hazardous wastes, decontaminate all facilities and equipment of hazardous waste residues (viz. agent) in-situ, and “clean-close” the facility in accordance with the facilities’ hazardous waste permits. In situ decontamination is expected to be achievable in most cases, but complete in-situ decontamination of all areas within the Agent Processing Building at PCAPP is probably not achievable because of the presence of objects having complex shapes, absorptive materials, and occluded spaces. Accordingly, some equipment is expected to be subjected to thermal decontamination through the MTU at PCAPP and the MPT at BGCAPP, which are planned to be used during closure for this purpose. Subsequent to

¹¹ Roger Dickerman, operations manager, BGCAPP, “Designing for Closure: A Three-Phase Approach for Closure of the Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP) Munitions Demilitarization Building (MDB),” presentation, May 25, 2011.

decontamination, most of the waste materials are expected to be cleared for ultimate disposition off-site using unventilated monitoring testing to ensure that vapor concentrations are less than the vapor screening level (VSL). At this point, the building will be systematically razed, largely by a demolition contractor, and the debris appropriately disposed of, for example, sent for recycling or to a RCRA-permitted hazardous waste landfill. Mechanized demolition will reduce manual interaction and minimize opportunities for dermal contact with various hazards, and the concentrations of any hazardous vapors will be lower as a result of natural ventilation.¹² The committee has no information about the planned closure strategy for BGCAPP and cannot explicitly comment on it here. Nevertheless, the handling, transportation, disposal, and documentation of the debris that will be generated during the closure of PCAPP and BGCAPP will be in accord with site-specific procedures, Department of Transportation requirements, and the site RCRA permit.

Waste disposition processes during closure are critical to the operation of BGCAPP and PCAPP, and will affect the efficiency and rate of the overall closure activities. The quantity of waste that will be generated will be large and diverse. Previous experience in closing the incineration demilitarization and other facilities managed by CMA substantiates this expectation.¹³ Slow waste disposition has the potential to significantly extend the closure schedule and increase the need for budget resources.¹⁴ This problem has been previously encountered during closure operations. At NECDF, insufficient space for the clearance, packaging, and shipping of waste required construction of new work spaces in existing buildings.¹⁵ Therefore, discussion of the wastes generated and associated decontamination processes is included in this report.

The extent of agent contamination will significantly affect the disposition of the wastes because contaminated waste materials generally cannot be disposed of unless they are decontaminated to a level consistent with the governing permits. Any special circumstances would have to be addressed in coordination with the state regulators. Therefore, an examination of the decontamination approaches is warranted. Further, decontamination must be validated. Therefore, the measurement of residual agent present in or on waste materials will be critically important. To address these considerations, a consideration of waste characterization capacity and efficacy is also discussed in this section.

Quantities and Characteristics of Anticipated Waste Streams

The quantity of waste materials generated will be large, and individual objects will be diverse in terms of materials of construction, shape, size, and ability to absorb, adsorb, or sequester agent. Many items will have the ability to sequester agent leading to situations where contamination will not be apparent. Residual agent can persist in occluded spaces, which can include cracks, crevices, pores, and absorptive materials such as organic polymers, posing the potential for unanticipated contamination in waste materials.

PEO ACWA has defined specific criteria for categorizing waste materials as contaminated, potentially contaminated, and never contaminated (clean), which enables effective decisions with respect to decontamination strategies to be used. The committee considers the waste categorization to be in accord with engineering best practices.

Items that are clean and that do not have any hazardous characteristics can be released for proper disposal or recycling as appropriate per the site permits. This state can be established based on process

¹² PEO ACWA, "Guidance on Facility Closure," memorandum, undated.

¹³ See the Introduction, above, where these plants are listed.

¹⁴ Amy L. Dean, senior project engineer, Chemical and Biological Applications and Risk Reduction, U.S. Army Futures Command, "Concepts for Site Closure," presentation to the committee on August 13, 2019.

¹⁵ Discussions between Jeffrey L. Brubaker, technical advisor to the site project manager, BGCAPP, and the committee on August 13, 2019.

knowledge (including location of origin) and by analytical characterization to clear the wastes.¹⁶ The process is carefully defined and reflects the complexity that will be encountered when closing BGCAPP and PCAPP. Potentially contaminated wastes that are cleared as being free of agent and are also free of other hazardous characteristics can also be disposed of by shipping them off-site. Shipping agent-free, nonhazardous materials for appropriate disposal off-site is the preferred disposition path for waste materials.

If the majority of wastes are uncontaminated or cleared, the rate at which these wastes are produced may exceed the rate at which they can be shipped. Potential limitations on the rate of waste shipments include space to hold materials awaiting characterization, lab testing capacity, space for staging waste materials to be shipped, hoisting and rigging equipment to move waste materials from the point of generation to the shipment point, packaging and wrapping materials, and personnel availability. These limitations have the potential to create bottlenecks that could slow the overall closure rate of BGCAPP and PCAPP.

Finding 3. Available space, packaging and wrapping materials, laboratory analytical capacity, and personnel resources may not support the rate of waste shipment needed to keep up with the rate of waste generation, and may limit the rate of overall closure activities. Based on prior closure experiences, the space for characterization, staging, and packaging wastes for shipment may be inadequate.

Recommendation 3. PCAPP and BGCAPP staff should estimate the rate at which waste will be generated and the associated space, equipment, and personnel needed to package and ship the waste. It should also identify, and potentially construct, sufficient staging areas for waste handling and storage.

Contaminated Waste Materials and Decontamination Strategies

A salient part of the closure strategy involves determining what items require decontamination. Items or materials exposed to liquid agent or agent aerosol will be managed as being contaminated with liquid agent. Agent-contaminated materials will require decontamination before they can be further processed (e.g., shipped off-site). Waste material disposition pathways and decontamination methods are selected based on history and extent of contamination and analytical characterization.¹⁷

At PCAPP, the decontamination strategy reflects implementation of the overall PEO ACWA guidance (CDPHE, 2018, Attachment I):

- Elimination of fluids;
- Removal of components and equipment too complex for disassembly;
- Exposure of occluded spaces;
- Surface decontamination;
- Thermal decontamination using the thermal treatment technologies at the sites, e.g., the MPT, MTU, and SDC;
- Scabbling of concrete floors; and
- Removal of sumps and trenches.

Many of these actions contribute to the overall demand on the resources available for decontamination, which can be accomplished by one of three general approaches: thermal decontamination, chemical decontamination, and physical decontamination.

¹⁶ PEO ACWA, "Guidance on Facility Closure," memorandum, undated.

¹⁷ PEO ACWA, "Guidance on Facility Closure," memorandum, undated.

Thermal Decontamination

Conceptually, thermal decontamination is the simplest approach because items and materials that have been heated to 1,000°F for 15 minutes are expected to be agent-free (CDPHE, 2018; KDEP, 2018). Ample past experience has demonstrated that these conditions effectively destroy agent (although agent that is somehow shielded from reaching these conditions can survive the process). Both the MTU at PCAPP and the MPT at BGCAPP are designed to provide these conditions. Accordingly, after thermal treatment in these conditions, aside from a final air monitoring cycle following thermal treatment, additional analytical characterization (e.g., manual sampling or laboratory analysis) is not performed. Thus, from a characterization perspective, this is an optimal decontamination treatment. Thermal decontamination is specified in the permit for decontamination of certain waste materials at both plants. At BGCAPP, both PPE and contaminated dunnage are permitted for decontamination in the MPT. However, the permit does not specify the use of the MPT for the decontamination of other waste items. Items with residual agent are allowed; however, nothing containing liquid agent is permitted in the MPT. At PCAPP, the MTU is intended for the thermal decontamination of metal casing of munitions, and likely is explicitly permitted only for this.

In addition to permitted uses, thermal decontamination using the MTU and MPT are frequently referenced as the fallback decontamination approach for difficult-to-decontaminate items. The quantity of objects needing decontamination and their sizes are such that the capacity and throughput of the thermal treatment units may be inadequate for the timely decontamination of the waste items and materials. If this turns out to be the case, the situation could significantly slow the overall rate of closure at BGCAPP and PCAPP. These considerations could result in greater demand than anticipated for thermal decontamination using the MTU and MPT and could exacerbate closure processing bottlenecks related to the throughput of waste requiring thermal decontamination.

At PCAPP, the supplemental decontamination unit and the autoclave are used to decontaminate dunnage, including filter media, hoses, rags, absorbent pillows, pumps and valves, PPE, and “other wastes” (CDPHE, 2018). After treatment, these decontaminated items may be shipped off-site to a TSDF permitted to receive these types of materials. Hence, these units will lessen the demand for thermal treatment through the MTU. However, these units do not heat waste materials to 1,000°F, and so may require analytical validation prior to release and shipment.¹⁸ The effect that these units will have on overall thermal decontamination processing rate estimates will need to be determined and taken into account when evaluating overall capacity for thermal decontamination at PCAPP.

Increasing the variety of items and materials that the thermal decontamination units at PCAPP and BGCAPP are permitted to treat might be helpful to conducting closure in an efficient manner. Potentially contaminated equipment containing occluded spaces (e.g., part of a robot, bearings, and gaskets) could be more easily thermally decontaminated compared to complete mechanical disassembly and the associated monitoring. Additional thermal decontamination would require modification of the permits to include treatment of a wider range of contaminated waste materials. The committee recognizes that the permit modification process is arduous and that only a small percentage of the waste might be affected. However, even a small percentage of the overall closure wastes could produce a bottleneck in the decontamination processes at the plants and have the potential to slow the overall closure of the plants.

The SDC has been, is being, and will be used to thermally decontaminate a variety of chemical munitions in a variety of configurations. Past experience with the ANCDF SDC showed that, while it was effective at destroying agent, agent penetrated the first of multiple containment regimes during

¹⁸ The supplemental decontamination unit heats materials to 500°F and the autoclave heats materials to 275°F in a steam environment. See PEO ACWA, “Heat Reduces Equipment, Waste Contamination at Pilot Plant,” *PCAPP News*, December 12, 2016, <https://www.peoacwa.army.mil/2016/12/14/heat-reduces-equipment-waste-contamination-at-pilot-plant/>.

operations, resulting in agent contamination where none was expected. Additionally, an ash byproduct was formed that required labor-intensive decontamination during closure (Leidos, 2014). The variety and number of products processed through the SDC could be significantly higher at BGCAPP, as the number of rounds that are overpacked, leaking, or geometrically unsuitable for primary processing is undetermined. The SDC could be used to thermally decontaminate a large variety of plant equipment, assuming that it could fit through the intake system and that the proper permitting documents are in place. If permitted, a single post-thermal-treatment monitoring for contamination could significantly reduce the monitoring and analytical testing burden required for complex hardware.

Finding 4. The thermal treatment units at BGCAPP and PCAPP could be used for decontaminating additional equipment and parts during closure compared to already planned uses. An expanded use of these units will produce more wastes ready and suitable for off-site disposal or recycling. Expanded use, however, will be limited by treatment capacity, geometric constraints, and permit conditions. It may also give rise to the presence of agent in unexpected places and the formation of residues.

Recommendation 4. BGCAPP and PCAPP plant staff should conduct a planning study that evaluates the intended use of existing thermal treatment units for decontamination during closure operations, determine whether thermal treatment will be rate limiting to the overall closure process, and explore the possible expanded use of thermal treatment. This study should include an evaluation of treatment capacity, anticipated treatment rates and durations, size and geometric constraints, necessary permit revisions, and the possibility for occurrences such as agent being in unexpected places and the formation of residues. As part of the study, PCAPP and BGCAPP staff should identify all items that could be processed by thermal treatment, any disassembly necessary for larger equipment to fit into the thermal treatment units, and an estimate of throughput. PEO ACWA should also evaluate modifications to the environmental permits to enable the increased use of the thermal treatment units for decontamination of a broader range of contaminated materials and the overall impact of expanded thermal decontamination to the closure process.

Chemical Decontamination

Chemical decontamination is effective for neutralizing or removing agent from waste materials, and is planned for use at PCAPP (CDPHE, 2018). It requires the use of decontamination solutions, which can range from water to sodium hydroxide and detergents. For example, in past closure campaigns, high-pressure water was used to remove agent from contaminated surfaces.¹⁹ Chemical decontamination may be used in tandem with thermal or physical decontamination. Time is required to allow the decontamination reactions to complete, but this is not expected to be limiting with respect to the overall closure schedule. Chemical decontamination produces spent decontamination solutions, which will add to the overall waste load. However, these solutions can be collected in the tanks permitted to hold spent decontamination solution or the 90-day hydrolysate storage tank that supports closure, and ultimately be sent to an offsite TSDF (CDPHE, 2018). The chemical decontamination approaches are thus not expected to add to the analytical characterization load because the contents of the spent decontamination solution tanks must already be analyzed prior to disposal or further processing. The use of chemical decontamination approaches will add to the overall volume of liquid waste produced during closure, but any extra quantity produced is not expected to be significant.

¹⁹ Amy L. Dean, senior project engineer, Chemical and Biological Applications and Risk Reduction, U.S. Army Futures Command, “Concepts for Site Closure,” presentation to the committee on August 13, 2019.

Physical Decontamination

Scabbling is expected to be the principal means of physically decontaminating surfaces that still need it after chemical decontamination efforts and monitoring have been conducted. It involves breaking up and removing the top 1/4 inch of a surface and converting it to particulate waste material. The waste is collected by a vacuum system with a hopper for dust collection. It is managed as hazardous waste and either treated on-site or shipped off-site for treatment and disposal (CDPHE, 2018). Further details regarding dust characterization for agent contamination were not provided in the PCAPP closure plan; however, it would be reasonable that such characterization would be needed prior to off-site shipment. Hence, there is the possibility that if more scabbling is needed than had been planned, an increased load on the analytical laboratory for agent clearance could result. The time required for conducting physical decontamination using scabbling is well-understood based on prior experience at JACADS, and thus it is not expected to impact the overall closure schedule at either plant.

Potential SDC Issues

An SDC was used extensively at ANCDF for the destruction of chemical munitions, and the experience with decontaminating it provides relevant experience regarding the issues likely to be encountered when closing the PCAPP and BGCAPP SDCs. The surfaces of the loading chamber were coated with a film, described as having a rough yet pliable texture.²⁰ This description suggests the potential for occluded spaces, or possibly the ability to absorb (and thus sequester) agent, and this expectation was supported by persistent detection of agent in the atmosphere in the area of the loading chamber.

Initial decontamination efforts employed physical scrubbing; however, this was problematic owing to access limitations. Subsequent decontamination efforts utilized a chemical cleaner consisting of a combination of hydrogen peroxide and sodium hydroxide solutions, along with other ingredients that “promote the solubilization of the agent, the oxidation reaction, catalysis, and surface interactions.” (Brickhouse et al., 2008) However, repeated application still resulted in difficulty achieving worker population limit (WPL) and general population limit (GPL) criteria for the components of the SDC. Last, steam cleaning was performed, which resulted in clearance of the SDC components. It was concluded that steam decontamination in combination with the chemical cleaner was the best approach available. The time required to work through this series of decontamination attempts was on the order of 2 months.

Finding 5. The portions of the SDC that do not reach the full thermal decontamination conditions have the potential to accumulate surface materials that have displayed the ability to harbor small quantities of agent. This situation results in detectable atmospheric concentrations that will impede or inhibit clearance and release of SDC components.

Recommendation 5. Significant experience was gained in SDC decontamination conducted at ANCDF. PCAPP and BGCAPP plant staff should conduct a detailed study of the Anniston Chemical Agent Disposal Facility decontamination efforts and develop a decontamination approach that accounts for difficulties similar to those encountered previously.

²⁰ E-mail communication between Tim Garrett, director of field operations, PEO ACWA, and James Myska, study director, National Academies, December 30, 2019.

Characterization Challenges

As noted above, waste materials originating from agent-contaminated locations in the plants will require decontamination and subsequent analysis for agent prior to release. There are a variety of approaches for conducting analysis to achieve clearance for release and appropriate off-site disposition, and all have specific strengths and weaknesses. The approach adopted by PEO ACWA is the unventilated monitoring test, in which a plastic enclosure, also known as a tent, encloses a putatively contaminated object and the system is then heated to 70°F if the ambient temperature is below that. The agent is allowed time to partition into the tent atmosphere, ostensibly reaching equilibrium. The agent concentration in the headspace of the tent is measured periodically using near-real-time monitors, such as the Automatic Continuous Air Monitoring System or Miniature Continuous Air Monitoring System units, which are configured to alarm at the VSL, which is equivalent to the short-term exposure limit (i.e., the STEL) concentration limits. Testing may also be conducted using the Depot Area Air Monitoring System, which employs sorbent tubes for longer monitoring periods compatible with the measurement of agent concentrations at the WPL and the GPL, needed for the unrestricted disposal of excess material.²¹

The unventilated monitoring test relies on the fact that as an agent volatilizes, concentrations will slowly increase within an enclosed volume containing a contaminated item. The increased concentrations enhance the detectability of the agent compared to measurement of vapor in a nonenclosed environment, where volatilized agent vapor will merely diffuse or convect away. Agent concentrations in an unenclosed atmosphere will not build up and will be lower compared to the enclosed case. Thus, a low or nondetect concentration obtained from the unventilated monitoring test ensures that levels in the unenclosed case will be protective, that is, the unventilated monitoring test provides an upper bound on the airborne concentration that could develop above a contaminated item.

A distinct advantage of the unventilated monitoring test is that it is useful for irregular materials having high surface areas, cracks and crevices, porous or permeable materials, and other features leading to occluded spaces. The unventilated monitoring test approach is also integrating in that it measures agent originating from all surface locations on a waste item. In this respect, it is superior to direct surface analysis techniques, such as surface wipes or concrete chips taken from contaminated areas, which frequently cannot access the many obstructed surfaces that will be encountered. These characteristics are consistent with the unventilated monitoring test being a best practice for detecting agent contamination on irregular materials capable of sequestering agent.

The downside of the unventilated monitoring test is that it is time consuming, requiring time to build the tent and then to heat the system to allow it to come to constant temperature. If large numbers of objects require unventilated monitoring testing, then the characterization task could be rate-limiting with respect to the overall closure rate owing to the time it takes. In addition, a high demand for unventilated monitoring testing will increase the need for analytical resources, notably for Miniature Continuous Air Monitoring System instruments and technicians.

The disposal of contaminated items requires that concentrations measured using the unventilated monitoring test be less than the VSL, which is equivalent to the short-term exposure limit. Contaminated items with monitoring results greater than or equal to the VSL may in fact be shipped off-site for treatment or disposal if this action is allowed under the sites' environmental and hazardous waste permits.²² Some of the items will be demolished and disposed of as waste, which requires that the concentrations derived from the unventilated monitoring test be below the appropriate public health levels (i.e., below the VSL, WPL, or GPL, as appropriate). If they are not, further decontamination will be required before the disposal of the waste materials.

²¹ PEO ACWA, "Guidance on Facility Closure," memorandum, undated.

²² Ibid.

Finding 6. The number of analyses needed to provide timely waste characterization of the extensive volume and quantity of the waste streams being generated may exceed the throughput capacity of the laboratory and monitoring systems to characterize and clear the waste. If this occurs, it may create a characterization bottleneck that could slow the overall rate of closure.

Recommendation 6. PCAPP and BGCAPP staff should estimate the number of measurements that will be needed as a function of schedule and determine whether the lab, instrumentation, and personnel resources will be capable of keeping up with the rate of waste generation. If not, the staff should investigate and identify mitigation strategies to prevent a slowdown in closure.

It may be worthwhile to evaluate the current state of the art in surface analysis to determine whether the demand for analytical resources needed for agent clearance might be lessened by using a surface analysis approach. In fact, surface sampling using wipes is planned as a validation of decontamination efficacy prior to the unventilated monitoring test.²³ Surface wipes and concrete chips from contaminated areas are to be analyzed using extraction-based analysis to provide validation of decontamination.²⁴ The advantage of direct surface sampling and analysis is that, for flat surfaces without occluded spaces, the approach obviates the need to conduct tent testing and the associated times required for building the tent, heating the volume, and equilibration. To some extent this time savings will be offset by the need for laboratory analysis, but the approach may merit evaluation to reduce the analytical load associated with clearing waste materials.

Finding 7. Unventilated monitoring testing will be conducted to ensure that all areas of equipment that have been exposed to agent will be monitored for agent rather than relying on surface testing. This is especially useful for equipment with complex characteristics and a high potential for occluded spaces. Due to the cycle time for unventilated monitoring, it may be more efficient to perform surface testing for small objects (e.g., less than 1 square foot surface area).

Recommendation 7. BGCAPP and PCAPP staff should continue to use unventilated monitoring testing for large pieces of equipment. It should also compare the efficiency of performing surface testing for small objects (e.g., less than 1 square foot surface area) compared to bulk unventilated monitoring, taking into account the full cycle time for clearing materials using each method (including the time to build and take down tents) and lab capacity.

WORKER SAFETY AND INDUSTRIAL HYGIENE

Overarching Worker Safety and Industrial Hygiene Assumptions and Best Practices

As the facility owner, PEO ACWA has an obligation to ensure that all individuals on the site—program personnel, contractors, sub-contractors, and visitors—are clear about the site hazards and are familiar with their roles and what they need to do during both normal and emergency situations. Safety is only as strong as the weakest link in the safety culture. Safety leadership and safety culture apply to all phases of the plants, including closure, and set the tone for all hazardous chemical operations. It is the organizational leadership that creates the safety culture (NAC, 2018; Porter and Grubbe, 2017). Over the

²³ Ibid.

²⁴ Ibid.

past two decades, both CMA and PEO ACWA have made worker safety and industrial hygiene their first concern: an enduring best practice. This leadership attention to safety and the resultant actions will be essential to the successful completion of the overall demilitarization program.

Safety at PCAPP and BGCAPP has also been very good, as evidenced by the sites' Star status in the Occupational Safety and Health Administration (OSHA) Voluntary Protection Program. The continuous and persistent involvement of management in safety, from actions to prevent safety incidents to the investigation and tracking of safety incidents, has created the current safety culture and ensured good operational outcomes for the chemical demilitarization program to date by:

- Making safety the first consideration of all activities;
- Daily management participation in safety activities, including daily meetings to review work that is planned and underway and any documentation changes;
- Management review of the results of all incident investigations and work pauses;
- Collaboration among program and contractor leadership to make safety metrics readily available for review by management and workers; and
- Encouraging high levels of participation in safety efforts by all site personnel.

A best practice identified from the closure of PBCDF is that all changes to plant-related documents were communicated daily to all personnel via e-mail and were posted to the PBCDF website. This ensured that personnel were notified in a timely manner of all document changes that could affect their work and that the current versions were always available. Additionally, update meetings were convened on a weekly basis with representatives from each department to discuss potential changes to work flows and equipment deactivations and the impact of these on other work processes and documents. This activity proved to be very effective in stimulating conversations that helped to ensure that project requirements were being met and safety maintained. Standard questions were developed to assist the staff with evaluating potential changes to work flows and equipment deactivations (URS, 2013).

Finding 8. It is vital that program management and leadership maintain their high level of commitment to safety culture as the operations wind down and transition to closure.

Recommendation 8. Program and plant management should continue to put safety first. This would include daily management involvement in safety including daily meetings to review work and any documentation changes, management participation in safety activities, requiring all staff to participate in safety activities, management review of all safety incident investigations and work pauses, and collaboration to ensure that safety metrics remain visible to managers and their respective workforces until completion of the project.

Safety Considerations During Closure Operations

Operations and closure work are not similar. Closure work presents:

- Frequently changing work conditions;
- Nonstandard tasks;
- Possible unexpected pockets of agent that could result in a higher potential for agent exposure; and
- Exposures to demolition-associated health hazards such as noise, carbon monoxide, diesel exhaust, silica (a common component of concrete and paint), lead (a common component of

many industrial paints, plumbing and piping), other heavy metals such as chromium and arsenic, and liquid nitrogen (OSHA, 2007; URS, 2013; Leidos, 2014; Fed. Reg., 2016).²⁵

There are three phases to closure work, as follows:

1. Testing for residual contamination,
2. Decontamination and equipment removal, and
3. Building demolition.

When planning for the transition from operations to closure, management must appreciate the complexity of the effort. Operations, deconstruction, and demolition may be under way simultaneously in different areas of the facilities. There may also be new hazards that were not a concern during operations. For example, during thermal treatment, items such as valves and pumps have a potential to experience pressure buildup. Also, activities such as line opening and the cutting of piping and other metal components, using either mechanical cutters or welding torches, presents the potential for the exposure of sequestered agent and presents the potential for worker exposure. In addition, new, nonstandard tasks will be introduced during closure. These changes increase the potential for safety incidents owing to increased complexity and unfamiliarity with the new tasks. To ensure that all aspects of safety and industrial hygiene receive adequate attention during the transition plan, collaboration between PEO ACWA program management, site representatives, and key contractor and subcontractor management is essential.

A robust Lessons Learned program was developed and shared by the legacy sites. Each site contributed important pieces to the methods used at subsequent sites for decontamination of equipment and surfaces potentially exposed to chemical agents.

The PCAPP and BGCAPP closure plans will determine the requirements for the deconstruction or demolition of buildings, the final disposition of the wastes generated during these operations, and the final state of any surrounding utilities and the ground. Because the prior neutralization facilities at ABCDF and NECDF are closed, the lessons learned from those facilities would be particularly useful for planning the closure of PCAPP and BGCAPP. The committee does not have access to these documents at this time, so it has offered general guidance based on the ANCDF and PBCDF closure reports and the committee's knowledge of best safety and industrial health practices.

Once the agent processing equipment and ancillary equipment has been removed from a space and the space has been decontaminated, the building deconstruction or demolition required by the closure plans can begin. General hazards in this phase of the work include, but are not limited to, a loss of structural integrity owing to the removal of pieces of floors, ceilings, or walls; the removal of electrical power and lighting systems without proper lockout/tagout; and removal of heating, ventilation, and air conditioning ductwork and system elements. Potential injuries include electric shock, crushing owing to unstable structures or improper rigging, heat stress, falls, strain and sprains, cuts, abrasions, and fractures.²⁶

The practice at the legacy chemical demilitarization sites was to develop work packages and train workers for operations and closure using duplicate equipment at a training center or by performing a "mock" operation in an uncontaminated area (URS, 2013).²⁷ These work packages established standard procedures and detailed instruction for the safest, most efficient manner to operate, decontaminate, and demolish the equipment and facilities.

One significant application of this practice to closure operations would be to practice the disassembly of large pieces of plant equipment. This work may include tasks that are nonroutine and of increased awkwardness owing to workers wearing PPE. Some of the equipment at PCAPP and BGCAPP

²⁵ Amy L. Dean, senior project engineer, Chemical and Biological Applications and Risk Reduction, U.S. Army Futures Command, "Concepts for Site Closure," presentation to the committee on August 13, 2019.

²⁶ Ibid.

²⁷ Ibid.

is complex and may not have been designed to be disassembled. Where conventional disassembly may be infeasible, it may be necessary to use a mechanical cutter, which may be robotic. Any cutting performed manually will need to account for hazards due to the potential aerosolization of residual agent or other hazardous contaminants during the cutting process.

Thus, to be effective, closure work packages need to be comprehensive, including the following:

- Job hazards analyses;
- Experiences and data from previous closures;
- Instructions from equipment vendors about how to best disassemble equipment;
- A determination of what equipment will need to be cut up; and
- Clear instructions for when to pause or stop work.

Last, at other sites, delays in work package approvals and absence of a sufficient backlog of approved work packages and related work pauses posed challenges in retaining trained workers.²⁸

Finding 9. It is unknown which equipment is amenable to manual disassembly and what equipment might need to be cut apart during closure.

Recommendation 9. Plant management personnel should carefully estimate the extent to which equipment will be disassembled versus cut or sheared into pieces and the resulting impact on the labor required for disassembly and labor required for analytical characterization, as well as the safety impacts of different disassembly methods.

Finding 10. There is a need to develop comprehensive closure work packages to safely implement closure work on a schedule that ensures workforce continuity and operational effectiveness.

Recommendation 10. Program management should develop closure work packages. This should be done by a variety of staff (e.g., engineers, safety personnel, and operations staff). The work packages should:

- Ensure that decontamination and equipment disassembly are well thought out and that all tasks and associated hazards are accounted for;
- Include job hazards analyses, experiences and data from previous closures, and instructions from equipment vendors about how to best disassemble equipment;
- Include instructions for the safe cutting or shearing of equipment that cannot be disassembled;
- Provide clear instructions for when to pause or stop work;
- Be drafted on a schedule that anticipates delays in approvals and maintains a sufficient backlog of approved work packages to maintain workforce continuity; and
- Ensure that there is an adequate number of trained, experienced workers in order to avoid bottlenecks.

Program and contractor management may want to explicitly address the differences in closure work from normal operations during meetings with workers and in training sessions. One approach that has shown to be successful in industrial operations is to plan and hold periodic safety retreats.²⁹ These are

²⁸ Ibid.

²⁹ For more information, see Danica Miller, “The Benefits of Safety Meetings,” EH&S Insider Blog, February 14, 2019, https://blog.wisebusinessware.com/safetyinsiderblog/safety_meetings.

events scheduled to brainstorm and to consider how best to lead and to conclude safe operations and closure of both the program and sites, away from the distractions of facility activities. Pre-retreat work would include identifying key milestones and identifying times of significant change and increased risk. Results could include:

- An improved sense of caring and alertness among the workforce and its supervisors as workers prepare for new, nonstandard, tasks;
- A better understanding among the broader workforce of how more dangerous tasks are to be executed; and
- More precise knowledge among management about items that require focused attention.

The closure of PCAPP and BGCAPP will represent the end of the entire U.S. chemical munition stockpile disposal program. Chemical demilitarization work has been relatively steady during the past two decades, resulting in a stable and experienced workforce. This work will be completed when these two sites close; there is no further stockpile to dispose of. In the past, some portion of the chemical demilitarization workforce, possessing highly specialized skills and experience, was able to move on to the next plant that was or would be in operation. Incentives were also offered to select personnel to encourage them to stay with the program.³⁰ That is not an option here because the entire program is ending; there is no further work for people to move on to. This leads to a concern that skilled, in-demand workers may leave for new opportunities before closure is completed. While the situation is different for PCAPP and BGCAPP (closure of a program versus closure of a site), financial incentives and postclosure retraining might be considered to retain skilled workers through the end of closure.

During the upcoming PCAPP and BGCAPP closure periods, due to workforce uncertainty, skilled workers may depart before closure is completed and new workers who are unfamiliar with the plants and processes might have to be hired. This would create a larger potential for gaps in the safety and industrial hygiene procedures and practices that could impact the overall program outcomes, such as illnesses, injuries, or possible OSHA and Environmental Protection Agency (EPA) citations. Aside from the impact of injuries and work stoppages to the site personnel, a deterioration of the current solid safety and industrial hygiene program could be detrimental to the closure schedule.³¹ Safety during JACADS closure, which had a worker retention program, was good as evidenced by the 12-month recordable injury rate from April 2001 through April 2003 of 2.0.³²

Finding 11a. The closure of the final two plants represents the end of the chemical weapon stockpile program representing potentially the last opportunities for the highly skilled workforce. Uncertainty within the labor force regarding future employment could impact safety performance. These concerns may be more significant than in the past because these plants are the last chemical demilitarization plants.

Finding 11b. There appears to be an effective relationship between PEO ACWA and the contract labor force at both PCAPP and BGCAPP. It will be vital to continue this relationship as PCAPP, BGCAPP, and the entire chemical stockpile disposal program enter closure.

³⁰ Amy L. Dean, senior project engineer, Chemical and Biological Applications and Risk Reduction, U.S. Army Futures Command, "Concepts for Site Closure," presentation to the committee on August 13, 2019.

³¹ "JACADS Closure Lessons Learned: Schedule Analysis," presentation to the final integrated process team meeting, on September 9-10, 2003, in San Francisco, Calif.

³² Rob Jones, Washington Demilitarization Company, "JACADS Closure Lessons Learned: JACADS Safety, Operations to Demolition," presentation to the final integrated process team meeting, on September 9-10, 2003, in San Francisco, Calif.

Recommendation 11. PEO ACWA should continue its effective relationship with contract labor, discuss the transition to closure activities. PEO ACWA and its contractors should consider programs that incentivize the workforce to stay through the completion of closure. These programs could include financial incentives or retraining programs that could make the workforce better able to obtain subsequent employment.

Another possible consequence of the departure of skilled workers prior to the end of closure is a lack of personnel trained in emergency response procedures and in the use of emergency equipment. It will be important for existing staff and new workers hired to replace skilled workers to participate in regular emergency response training, training in the use of specialized equipment, and mock drills. A best practice is for all such training to be conducted at least annually and whenever there are significant changes in plant structure, equipment, or work procedures that significantly impact the safety environment.

Finding 12. If a serious incident occurs during closure, proper and readily-available emergency response equipment and trained response personnel are essential to mitigate any potential negative outcomes.

Recommendation 12. Program management should ensure that appropriate emergency response capability is always available onsite through the entire closure process. Actions such as regular emergency response training, training in the use of specialized equipment, and mock drills can help accomplish this. Such training should be conducted at least annually and whenever there are significant changes in plant structure, equipment, or work procedures that significantly impact the safety environment.

Experience at ANCDF and PBCDF showed that the more experienced workers were with the operations and equipment, the safer and more efficient the task. Some legacy sites employed contractors specifically with demolition expertise.

Finding 13. The use of a contractor with demolition expertise and proper demolition equipment is prudent.

Recommendation 13. When possible, program management should retain experienced workers to work on equipment with which they are familiar. It should be noted that some retraining may be necessary to refresh workers. Program management should also consider the use of specialized demolition contractors.

Hazards, Industrial Hygiene, and Personnel Protection

A wide variety of hazards, both agent and nonagent, will be present during closure. These hazards are addressed in practice with a combination of management controls, medical monitoring, and PPE.

Agent Hazards

The determination of the potential for exposure to agent is accomplished via air monitoring and the Army methods of detecting surface contamination on materials as outlined in the section “Decontamination and Hazardous Wastes,” earlier in this document. Planning for PCAPP and BGCAPP closure can take advantage of the past experience of other closures, allowing planners to anticipate areas

that might potentially have higher levels of agent contamination.³³ There may also be unexpected sources of agent hazards. One example would be the potential for agent to leak through pump seals into the lubricating oil.

The requirements for worker PPE to protect against chemical agent are detailed in U.S. Army (2018). PPE is classified according to four levels (A to D), where level A provides the greatest level of protection and level D the least. The selection of PPE takes into consideration a variety of factors, including the following:

- The identified hazard;
- The routes of potential exposure (i.e., inhalation, skin absorption, ingestion, and injection);
- The performance of the PPE materials in providing a barrier to these hazards;
- Matching the PPE to task-specific conditions, such as the tightness of the space or the need for dexterity and grip;
- Task duration; and
- Heat stress (U.S. Army, 2018).

As closure progresses and hazards are removed, the required level of PPE can generally be reduced, ranging from the maximum Level A PPE to precautionary Level D. Even when equipment and walls and the like have been decontaminated, residual liquid agent can still remain in low spots in piping.³⁴

Finding 14. Worker protection requirements may vary for a given contamination level, depending on the presence of liquid agent and the tasks at hand. PPE can generally be downgraded as closure progresses and areas are decontaminated.

Recommendation 14. Program management should continue to carefully assess conditions during closure and continue enforcing strict adherence to PPE guidelines. Any relaxation of PPE requirements should not occur until data can be provided to support the change. Data from previous closures for similar PPE should be referenced to avoid surprises.

Nonagent Hazards

In addition to the hazards associated with agent, the closure of any type of industrial facility has inherent safety and health hazards that may not have been present during operations. These hazards may also require PPE to protect workers. Activities such as cutting metal, demolition of walls and floors, and removal of electrical and hydraulic equipment necessitate robust industrial hygiene and safety programs. There may be occasions when workers are in areas that have been cleared of agent, thus not subject to extensive agent-related PPE requirements, but they may still be subjected to significant exposures to the other health hazards such as noise, crystalline silica, asbestos, PCBs, lead, other heavy metals, diesel exhaust, carbon monoxide, and nitrogen. Silica and heavy metals such as lead could be released as structural materials are demolished (URS, 2013; Leidos, 2014). There is potential for worker exposures to diesel exhaust and carbon monoxide from demolition and materials-moving equipment having internal combustion engines and generators, especially in areas where ventilation systems may have been taken out of service or removed. Some diesel exhaust components can cause chronic health hazards. Workers

³³ Amy L. Dean, senior project engineer, Chemical and Biological Applications and Risk Reduction, U.S. Army Futures Command, “Concepts for Site Closure,” presentation to the committee on August 13, 2019.

³⁴ Ibid.

that will be performing operations such as hand or Brokk scabbling may have significant noise exposure.³⁵ If nitrocision scabbling, which utilizes cryogenic liquid nitrogen as an abrasive medium, is used, potential hazards include the unique hazards of nitrogen asphyxiation in confined areas and freeze-burns from skin contact with liquid or gaseous nitrogen (URS, 2013).

OSHA has specific standards and associated requirements for crystalline silica (identified as a human carcinogen) and lead. For workers exposed to silica or lead above the respective action levels, OSHA prescribes specific medical monitoring beyond that which would be conducted for agent, whether or not respiratory protection is worn. Under the relatively new OSHA standard 1926.1153 (effective in 2016), not in place during previous closures, the crystalline silica action level is 25 $\mu\text{g}/\text{m}^3$ as an 8-hour time-weighted average, and medical monitoring includes medical history, a physical examination by a health care provider, a chest x-ray (meeting specified requirements and read by a National Institute of Occupational Safety and Health Administration-certified B Reader), pulmonary function testing, and testing for latent tuberculosis infection (OSHA, 2016). Where employee exposure to lead exceeds the action level of 30 $\mu\text{g}/\text{m}^3$ (after factoring in the respirator protection factor), OSHA standard 1926.62 (effective in 2019) specifies requirements for industrial hygiene and medical monitoring that includes biological monitoring in the form of blood sampling and analysis for lead and zinc protoporphyrin levels (OSHA, 2019).

Finding 15. In addition to agent exposure, other health and safety hazards may be present during closure. These may include noise, crystalline silica, lead, other heavy metals, carbon monoxide and exhaust from gasoline and diesel-powered equipment operated in confined spaces, or nitrogen/oxygen deficiency if nitrocision scabbling is performed. These hazards may necessitate PPE for workers.

Recommendation 15a. During closure, plant management should ensure that health and safety hazards associated with materials, other than agent, receive adequate attention. Workers who will have potential exposures to silica and lead should receive appropriate medical monitoring, as laid out in the Occupational Safety and Health Administration regulations 29 CFR 1926.1153 and 1926.62, respectively. Attention should be given to ensure that appropriate personal protective equipment for these hazards is worn, even in areas that have been cleared of agent exposure.

Recommendation 15b. Plant safety personnel should monitor carbon monoxide, diesel exhaust, and oxygen levels in areas where equipment is being used, especially where there may be limited ventilation. Crews should be prepared to ventilate the area with auxiliary equipment and have evacuation plans in place.

Ergonomics

Closure work also presents significant ergonomics hazards. The equipment used in past closure activities was generally heavy and awkward, placing employees in working positions that put them at risk for injury owing to poor body mechanics. Ergonomics hazards result in soft tissue injuries, especially in workers whose musculature and connective tissues may be compromised due to previous work, personal activities, or aging. These injuries can account for a significant portion of an operation's overall injuries. Moreover, ergonomics injuries are oftentimes not related to a specific event but occur over time, thus identifying these injuries, which cannot be readily seen, relies on individual self-reporting. Therefore, ergonomic issues require a different set of procedures in the workplace than those commonly used for preventing injuries that are more straightforward or obvious.

³⁵ Ibid.

A best practice identified at PBCDF was to have all maintenance personnel attend commercially available training that teaches methods for preventing strains and sprains through techniques for transferring forces away from vulnerable areas of back, shoulders, neck, and knees. This training was very well received by the employees (URS, 2013). Best practices include annual ergonomic safety training and addressing any special ergonomic issues for a specific task in the comprehensive work packages discussed above.

Finding 16. There are various ergonomic risks present during closure work. Annual ergonomic safety training and addressing any special ergonomic considerations in work packages would help to mitigate these risks.

Recommendation 16. Program management should provide appropriate annual ergonomic safety training to workers who have increased risk of injury due to their closure duties. Any special ergonomic considerations for a task should be addressed in the comprehensive work package for that task.

ENVIRONMENTAL PROTECTION, REGULATIONS, AND PERMITTING

When closing BGCAPP and PCAPP, PEO ACWA must comply with the requirements of several environmental regulatory regimes, including those established under the federal CAA, Clean Water Act, and RCRA, as well as their state counterparts. The most challenging requirements are likely the federal and state hazardous waste requirements under RCRA and corresponding state laws, as they relate to closure and the classification and management of wastes generated or handled during closure.³⁶

Both Kentucky and Colorado have been authorized by the EPA to implement most of their hazardous waste regulations in lieu of the federal RCRA regulations. However, in situations where these states have not yet been authorized for certain RCRA regulations promulgated pursuant to the 1984 RCRA amendments, those federal regulations are effective until such time that the states adopt them and are authorized for them. For this reason, and because the federal requirements serve as the foundation for the rules in both states (and in any other states to which wastes from the closure activities may be sent), both the federal and state regulations are addressed here.³⁷

Closure Requirements

The federal and state regulations require hazardous waste facilities in general—and facilities managing chemical munitions that qualify as hazardous wastes in particular—to be closed in a manner that controls, minimizes, or eliminates postclosure releases of hazardous wastes or hazardous constituents as necessary to protect human health and the environment.³⁸ Additional requirements apply to particular types of hazardous waste management units, such as container storage areas, tank systems, containment buildings, and miscellaneous treatment units.³⁹ These broad closure performance standards are translated into more detailed requirements through a closure plan that must be approved by the relevant

³⁶ See, for example, NRC (2010a), p. 35.

³⁷ See, for example, Fed. Reg. (2018), discussing the history and scope of Kentucky authorization, and Fed. Reg. (2012), discussing the history and scope of Colorado authorization.

³⁸ See 40 C.F.R. § 264.111 (general closure performance standard) and § 264.1202 (closure standard for hazardous waste munitions storage); 6 CCR 1007-3 § 264.111; and 401 KAR 39:090 § 1.

³⁹ See, for example, 40 C.F.R. §§ 264.178 (containers), 264.197 (tank systems), and 264.1102 (containment buildings); 6 CCR 1007-3 §§ 264.178, 264.197, and 264.1102; and 401 KAR 39:090 § 1.

permitting agency as part of the initial permitting process for the facility or subsequent permit modification(s).⁴⁰

One of the fundamental components of a closure plan is the selection of the desired end-state of the facility. A facility that will be released to residential or unrestricted use after closure will have to be cleaned to more stringent standards than a facility that will be limited to industrial use after closure. To the extent that the intent is to keep certain structures or equipment in place after closure for future use, the focus of the closure plan will be on decontamination rather than demolition and removal.

The current permit for BGCAPP requires that a closure plan be submitted to the Kentucky Department of Environmental Protection no later than the first receipt of hazardous waste and must be approved before closure activities are initiated (KDEP, 2018, Appendix A, Item 3). A preliminary closure plan was submitted in mid-January 2020 just before main plant operations commenced. The current permit for PCAPP, in contrast, does include a closure plan (CDPHE, 2018, Attachment I). This plan is considered preliminary and in-depth closure planning is anticipated to occur during PCAPP operations, resulting in revisions being submitted to the Colorado Department of Public Health and Environment for review and approval (CDPHE, 2018). According to the PCAPP closure plan, soil or groundwater contamination is not anticipated, and all equipment and structures will be dismantled and sent off-site for disposition (generally after being treated on-site, as necessary, to meet certain decontamination standards). In this way, the facility is expected to be “clean-closed” without the need for any postclosure care or any covenants or restrictions on future activities at the site. To the extent that circumstances change, the preliminary closure plan for PCAPP will need to be amended through permit modification. Indeed, some modifications to the detailed requirements of the plan are expected in any event, although the plan has apparently been developed to minimize the need for such modifications (CDPHE, 2018).⁴¹ Depending on the nature of the modifications, the process may be time-consuming and may require public participation.⁴² After closure is ultimately completed, a professional engineer must certify that the facility was closed in accordance with the specifications in the approved closure plan, and documents supporting the certification must be submitted to regulatory authorities upon request.⁴³

During the closure of other chemical agent disposal facilities, it was found that early and frequent communications with regulators and the professional engineer, who would be providing the closure certification, as well as careful documentation of such communications, were important in ensuring timely modifications to the closure plans and eventual certification of closure. The closure report for PBCDF further stated that it was a best practice to encourage site visits by regulators as often as possible throughout the closure process (URS, 2013, p. 113).

Both BGCAPP and PCAPP are located on larger installations that have separate hazardous waste permits for other reasons (e.g., the ongoing storage of chemical munitions to be processed at BGCAPP and PCAPP).⁴⁴ While this report does not address the requirements under these larger facilities’ permits for the closure of hazardous waste units and RCRA corrective actions for any past releases at solid waste management units, it is conceivable that the closure of PCAPP and BGCAPP might have an impact on the

⁴⁰ See, for example, 40 C.F.R. §§ 264.112 and 270.14(b)(13); 6 CCR 1007-3 §§ 264.112 and 100.41(a)(13); and 401 KAR 39:090 § 1 and 39:060 § 5(1).

⁴¹ CDPHE (2018), Attachment I, indicates that the closure plan is designed to enable closure to “proceed without the need to initiate *extensive* modifications to the permit” (emphasis added) (p. I-3) and discusses procedures for modification of the closure plan (pp. I-50 to I-51).

⁴² See 40 C.F.R. Part 270, Subpart D; 6 CCR 1007-3 § 100.6; and 401 KAR 39:060 § 5(1).

⁴³ See 40 C.F.R. § 264.115; 6 CCR 1007-3 § 264.115 (specifying that the professional engineer providing the certification must be independent); and 401 KAR 39:090 § 1.

⁴⁴ PCAPP is situated on the Pueblo Chemical Depot. BGCAPP is part of the larger Blue Grass Chemical Activity, both of which are tenants on the Blue Grass Army Depot.

larger facilities' permits. It may be advisable to coordinate the closure of BGCAPP and PCAPP with such closure and corrective action activities for the larger facilities, to the extent practicable.⁴⁵

Finding 17. Early and frequent communications with regulatory authorities, and documentation of such communications, is important in ensuring timely modifications to closure plans and ultimate certification that closure was properly performed.

Recommendation 17. When planning and executing closure, PCAPP and BGCAPP management should reach out to regulatory authorities early and on an ongoing basis, including encouraging site visits throughout the closure process.

Finding 18. It may be advisable to coordinate the closure of BGCAPP and PCAPP with closure and corrective action activities for the larger installations on which they are located, to the extent practicable.

Recommendation 18. PCAPP and BGCAPP plant management should make sure that plant closure is appropriately coordinated with closure and corrective action activities for the larger facilities on which are located.

Classification of Wastes from Closure Activities

Wastes generated or managed during closure will be classified as hazardous wastes under federal and state regulations if they exhibit a characteristic property of hazardous wastes or are specifically listed as hazardous wastes.⁴⁶

There are four characteristics under the federal and state regulations that cause a waste to be designated as hazardous: ignitability, corrosivity, reactivity, and toxicity (based on whether the wastes are capable of leaching certain metals, pesticides, or common organic chemicals in concentrations above specified levels during a particular laboratory test).⁴⁷ The EPA has stated that it “believes that the chemical agents and munitions in the military stockpile ... exhibit at least one of the characteristics.” (Fed. Reg., 1997, p. 6,633). In addition, the current permits for PCAPP and BGCAPP provide additional detail on the characteristics that will potentially apply to the chemical agents and munitions.⁴⁸ However, the treatment residuals and other wastes generated or managed during closure may or may not exhibit the same characteristics as the chemical agents or munitions themselves. Moreover, some of these wastes may exhibit characteristics unrelated to the chemical agents. Accordingly, it will be necessary to make a determination, at the point of generation for each waste, as to whether the waste is characteristically hazardous, based on testing, generator knowledge of the materials and processes used in generating the

⁴⁵ See, for example, NRC (2010a), p. 45, stating, in reference to closure of the baseline incineration chemical agent disposal facilities, that “it would be prudent for the Army to prepare closure planning documents that pertain specifically to closure of the [separately permitted storage units] and to obtain regulatory authority approval for these planning documents well before chemical agent disposal facility closure begins, so as not to impede closure plans for the chemical agent disposal facilities. In addition, closure activities should be coordinated.”

⁴⁶ See 40 C.F.R. § 261.3(a)(2); 6 CCR 1007-3 § 261.3(a)(2); and 401 KAR 39:060 § 3(1).

⁴⁷ This test is the Toxicity Characteristic Leaching Procedure, which is designed to simulate what might leach out if the wastes were disposed in a municipal solid waste landfill. See 40 C.F.R. §§ 261.21-261.24; 6 CCR 1007-3 §§ 261.21-261.24; and 401 KAR 39:060 § 3(1).

⁴⁸ See KDEP (2018), Sections B.III.A(1)-(2); and CDPHE (2018), Attachment D, pp. D-2 to D-4, Table D-2-3, and Table D-5-1.

waste, or some combination of the two.⁴⁹ Testing may prove to be especially challenging for heterogeneous closure wastes.

The permit for PCAPP provides some limited information on classification of closure-related wastes in its preliminary closure plan and Waste Analysis Plan, but the relevant parts of these plans may need revision as PCAPP approaches and enters closure. As noted above, BGCAPP submitted a preliminary closure plan in mid-January 2020 prior to beginning main plant operations. The committee did not have an opportunity to review this plan.

With respect to the hazardous waste listings, chemical agents and munitions and their treatment residues are not specifically listed as hazardous wastes under the federal RCRA regulations (although a limited amount of closure wastes might be federally listed as hazardous wastes for reasons unrelated to the chemical agents, such as in the case of certain spent solvents or discarded unused commercial chemical products).⁵⁰ However, both the Colorado and Kentucky regulations list chemical agents and related materials as hazardous wastes. A detailed listing can be found in Attachment E.

The primary importance of these state listings is that the listed wastes are classified as hazardous wastes regardless of whether they exhibit any hazardous waste characteristics. Moreover, mixtures of listed wastes with any other wastes, as well as solid wastes derived from the treatment, storage, or disposal of listed wastes, are similarly classified as hazardous wastes.⁵¹ Thus, while some derivative wastes from the treatment of chemical agents or munitions are separately listed (see Attachment E—K901 and K903 in Colorado, and N201 through N902 in Kentucky), even those treatment, storage, or disposal derivative wastes (and mixtures) that are not specifically listed qualify as hazardous wastes. In general, the only way that any of these wastes may be excluded from hazardous waste regulation is if they are delisted through a complex and time-consuming process that may not be practical for closure wastes at these two facilities.⁵² The facility and program managers may not be concerned about the classification of the materials if they intend to manage the wastes as hazardous wastes in any event (e.g., in order to address public concerns or to minimize potential long-term liabilities).

Environmental media (e.g., soil or groundwater) and debris (e.g., metal, concrete, or personal protective equipment) that contain listed wastes generally must also be managed as hazardous wastes, unless and until they are treated to the point that they no longer contain hazardous waste (e.g., they do not exhibit a characteristic and do not contain any hazardous constituents from the listed hazardous wastes above health-based levels).⁵³ In addition, debris generally does not have to be managed as hazardous waste if it has been treated using certain extraction or destruction technologies, it is not characteristically hazardous, and certain treatment performance criteria have been satisfied.⁵⁴ However, certain aspects of the state regulations may depart from these general requirements for environmental media and debris as they relate to closure wastes at PCAPP and BGCAPP. As noted above, the Colorado regulations specifically list soil, water, debris, and containers contaminated with chemical agents or their treatment derivatives as hazardous wastes (K902), which may mean that even if such materials are treated to the point where they no longer contain chemical agents or their treatment derivatives, the materials would continue to be considered hazardous waste because they are derived from treatment of listed hazardous wastes (unless the waste items are delisted).⁵⁵ However, the preliminary closure plan for PCAPP indicates that treatment by extraction or destruction may enable debris to be managed as nonhazardous waste

⁴⁹ See 40 C.F.R. § 262.11(d); 6 CCR 1007-3 § 262.11(d); and 401 KAR 39:080 § 1(1).

⁵⁰ See 40 C.F.R. Part 261, Subpart D.

⁵¹ See 40 C.F.R. §§ 261.3(a)(2)(iv) and (c)(2)(i); 6 CCR 1007-3 §§ 261.3(a)(2)(iv) and (c)(2)(i); and 401 KAR 39:060 § 3(1).

⁵² See 40 C.F.R. § 261.3(d)(2); 6 CCR 1007-3 § 261.3(d)(2); and 401 KAR 39:060 § 3(1). See also NRC (2010a), p. 36, stating that the delisting process is “often arduous and prohibitively expensive.”

⁵³ See, for example, 40 C.F.R. § 261.3(f)(2) (debris); 6 CCR 1007-3 § 261.3(f)(2); 401 KAR 39:060 § 3(1); and Fed. Reg. (1996; environmental media).

⁵⁴ See 40 C.F.R. § 261.3(f)(1); 6 CCR 1007-3 § 261.3(f)(1); and 401 KAR 39:060 § 3(1).

⁵⁵ See 6 CCR 1007-3 § 261.32.

(CDPHE, 2018, Attachment I, pp. I-20 to I-21). The Kentucky regulations, unlike the Colorado regulations, do not list environmental media or debris contaminated by chemical agents; rather, they list certain uncontaminated debris (N101 and N102).⁵⁶ Moreover, they incorporate a provision in the federal regulations stating that “[a]t closure of a military magazine which stored hazardous waste ... the owner or operator must remove or decontaminate all waste residues, contaminated containment system components, contaminated subsoils, and structures and equipment contaminated with waste, and manage them as hazardous wastes unless [40 C.F.R.] § 261.3(d) [concerning delisting] applies.”⁵⁷ These provisions may suggest that decontaminated media and debris, and even some debris that was never contaminated, will be regulated in Kentucky unless they are delisted.

One type of debris—scrap metal—presents a special case. The federal and state regulations state that scrap metal destined for recycling is either excluded or exempt from hazardous waste regulation.⁵⁸ This is true under the hazardous waste regulations even if the scrap metal is somewhat contaminated with hazardous waste, although the presence of liquid, powder, or dust (especially in “significant” quantities) may obviate the exclusion or exemption.^{59,60,61} Thus, to the extent that scrap metal from closure operations is deemed suitable for recycling and is sent for recycling, it will not be regulated as a characteristic or listed hazardous waste. The PCAPP Waste Analysis Plan establishes criteria for recycling at least one type of scrap metal (i.e., processed munitions bodies) (CDPHE, 2018). However, while other chemical agent disposal facilities have been able to take advantage of the scrap metal exclusions or exemptions during closure, some of those facilities have found recycling of scrap metal to be a challenge. For example, cleaned metals may sometimes retain an unacceptable odor or may have residual contamination that interferes with tests to show whether the criteria for recycling are met (URS, 2013). This was also noted in an earlier National Academies report:

The [steel hydrolysate] tanks [at ABCDF] were cleaned, but an odor caused by the presence of residual hydrolysate was present. Consequently, the recycling alternative was not considered viable. ... Attempts were also made to release titanium tanks at ABCDF to allow recycling. The tanks were tented and monitored to determine if they would meet the general population limit (GPL) for mustard agent. However, monitoring results were invalidated by interference from residual hydrolysate. ...[Thus] [t]he steel from the ABCDF hydrolysate storage tanks and the titanium tanks were landfilled as hazardous waste. (NRC, 2010a, pp. 43-44)

In light of this past experience, even cleaned metals from chemical demilitarization processes might have certain characteristics that would make taking advantage of the exclusion or exemption for recycled scrap metal impractical.

⁵⁶ See 401 KAR 39:060 § 3(4). More detail can be found in Attachment E of this report.

⁵⁷ See 40 C.F.R. § 264.1202(a), incorporated by reference in 401 KAR 39:090 § 1.

⁵⁸ See 40 C.F.R. §§ 261.4(a)(13) and 261.6(a)(3)(ii); 6 CCR 1007-3 §§ 261.4(a)(14) and 261.6(a)(3)(ii); and 401 KAR 39:060 § 3(1).

⁵⁹ See, for example, Fed. Reg. (1985), p. 624, stating that scrap metal does not include “metal-containing wastes with a significant liquid component.”

⁶⁰ Denit (1993), “a steel aerosol can that does not contain a significant amount of liquid would clearly meet the definition of scrap metal ... and thus would be exempt. ... Aerosol cans that have been punctured so that *most* of any liquid remaining in the can may flow from the can ... and drained ... would not contain significant liquids” (emphasis added).

⁶¹ Straus (1986); metal pieces qualify as scrap metal if they “only contain as [sic] oily film.”

Management of Wastes During Closure

Depending on the nature and classification of the wastes generated and managed during closure (as discussed above), many, if not most, of them may be handled in much the same way as wastes generated or managed during the operation of BGCAPP and PCAPP, in accordance with applicable regulatory and permit requirements. However, as the facilities are dismantled significant changes to how wastes are managed are likely to be required (although careful design of the facilities and sequencing of closure activities may help minimize the extent of the changes needed). Some of these operational changes may require modifications to the closure plans or other parts of the hazardous waste permits for the two facilities (and perhaps modifications to other permits, such as those issued under CAA). However, certain storage and nonthermal treatment activities during closure could potentially be performed outside the terms of a permit—for example, in accordance with the requirements of the conditional exemption from permitting for hazardous waste generator accumulation units (e.g., containers, tanks, or containment buildings).⁶² It may also be possible to obtain temporary authorization for up to 180 days (renewable once) for certain closure activities, without obtaining a permit modification.⁶³ Some closure-related wastes may best be managed by being transported off-site to a properly permitted TSDF, subject to any regulatory or permit restrictions on such off-site management.

The relevant statutes, regulations, and permits impose a number of substantive requirements that may be especially challenging for waste management during closure. Some of the key requirements are highlighted below. While requirements imposed solely by permit may be amenable to change through permit modification, requirements imposed by statute or regulation may be less readily changed. To the extent that some of the closure wastes might be hazardous solely due to a state hazardous waste listing, the requirements for ultimate disposition of such wastes could potentially be reduced by shipping the wastes to another state where they are not classified as hazardous.

Kentucky Chemical Agent Treatment Requirements

Kentucky law generally requires that facilities treating or disposing of chemical agents provide assurance that each of the relevant agents (i.e., VX, GB, and H) will be treated to a destruction or neutralization and removal efficiency (DRE) of 99.9999 percent under all operating conditions.⁶⁴ This requirement has been incorporated into the Kentucky hazardous waste regulations and the permit for BGCAPP.⁶⁵ In addition, the permit establishes detailed concentration limits that must be achieved before materials can be released from one unit to another or shipped off-site.⁶⁶ These requirements may be challenging during closure, because some closure-related wastes may come from points in the treatment train before 99.9999 percent DRE was achieved (although such wastes might not qualify as wastes subject to the 99.9999 percent DRE requirement), and opportunities for reprocessing to meet that standard or the other permit standards may no longer be available owing to the decommissioning and removal of equipment.

⁶² See, for example, 40 C.F.R. § 262.17; 6 CCR 1007-3 § 262.17; and 401 KAR 39:080 § 1(1). Fed. Reg. (1986), p. 10,168, “treatment in [unpermitted generator] accumulation tanks or containers is permissible ... provided the tanks or containers are operated strictly in compliance with all applicable standards.”

⁶³ See 40 C.F.R. § 270.42(e); 6 CCR 1007-3 § 100.63(e); and 401 KAR 39:090 § 1 and 39:060 § 5(1).

⁶⁴ See KRS 224.50-130(3)(a).

⁶⁵ See 401 KAR 39:090 §§ 6(2)(a) and (3); and KDEP (2018), Sections B.II.C(9), B.III.A(5)(a)-(d), B.III.A(7)(a), and B.III.X(1)(a).

⁶⁶ See, for example, KDEP (2018), Sections B.III.A(5), (6), (10), and (11).

Colorado Chemical Agent Treatment Requirements

The preliminary closure plan for PCAPP indicates that the extent of treatment and decontamination required will be evaluated throughout the closure process. However, it states that “[e]quipment and areas that have contacted liquid agent” will be decontaminated and will be eligible for shipment off-site if they meet the “action level criterion for disposition” of less than 0.7 of the mustard VSL (CDPHE, 2018, Attachment I, p. I-18). Importantly, such decontaminated materials, although eligible for shipment off-site, may still qualify as hazardous wastes, given that the PCAPP Waste Analysis Plan states that wastes above 0.2 VSL will generally be classified as listed hazardous wastes, and wastes below 0.2 VSL may still be classified as listed hazardous wastes if there is documented evidence of liquid agent contamination. In addition, as noted above, wastes derived from listed hazardous wastes (regardless of how far below the VSL they may be) are generally also considered listed hazardous wastes, with limited exceptions. The Waste Analysis Plan sets a different standard for at least one type of scrap metal (i.e., processed munitions bodies) to be sent for recycling—namely, a GPL of less than 0.00002 mg/m³ for mustard agent (CDPHE, 2018, Attachment D). As noted above, scrap metal destined for recycling is generally excluded or exempt from hazardous waste regulation.

LDR Treatment Standards

Under federal and state regulations, hazardous wastes are generally prohibited from being placed on the land, for storage or disposal, unless they first meet treatment standards under the LDR program. The EPA has issued treatment standards, which are effective in Kentucky and Colorado, for all of the characteristics that closure-related wastes may exhibit. Importantly, many of these treatment standards require not only removal of the hazardous waste characteristics but also treatment of all “underlying hazardous constituents” until they are below certain “universal treatment standard” levels.⁶⁷ Thus, closure-related wastes may need to be treated to meet stringent standards for a variety of metals and organic constituents other than the chemical agents. Some of this treatment, however, might be done at a permitted off-site treatment facility, and there may be exceptions if the treated material belongs to a different treatability group than the original waste or if the facility applies for and receives a treatability variance. Colorado (but not Kentucky) has also issued its own LDR treatment standards for some of the state-only listed chemical agent-related wastes discussed above (i.e., various types of K901 and K903 hydrolysates from particular munitions at specific points in the treatment process, and various chemical agents in hydrocarbon solvents used as calibration standards)—6 CCR 1007-3 § 268.40. These treatment standards include limits on several metal and organic constituents that are substantially the same as the EPA universal treatment standard levels. The Colorado treatment standards also require that chemical agents be nondetectable in hydrolysate wastes, and chemically oxidized in calibration standard wastes. The state treatment standards for other chemical agent-related wastes are “reserved.”⁶⁸

⁶⁷ See, for example, 40 C.F.R. § 268.40; 6 CCR 1007-3 § 268.40; 401 KAR 39:060 § 4. The LDR program establishes alternative treatment standards for certain characteristic debris, allowing such debris to be treated only to remove the characteristics, if specified treatment methods are used. See 40 C.F.R. § 268.45(a)(2); 6 CCR 1007-3 § 268.45(a)(2); and 401 KAR 39:060 § 4. Such alternative treatment standards have been applied extensively during closure at other chemical agent destruction facilities (URS, 2013).

⁶⁸ See 6 CCR 1007-3 § 268.40.

LDR Storage Prohibition

Under federal and state regulations, the storage of hazardous wastes subject to LDR restrictions is generally prohibited unless it is solely for the purpose of accumulating such quantities as necessary to facilitate proper recovery, treatment, or disposal. Storage beyond 1 year is presumptively impermissible.⁶⁹ The EPA has issued an exception for “[w]aste military munitions that are chemical agents or chemical munitions,” but the Kentucky regulations explicitly reject that exception and the Colorado regulations do not include a comparable exception.⁷⁰ Moreover, the EPA’s exception might not apply to closure-related wastes that do not qualify as chemical agents or munitions (e.g., treatment residuals). As a result, on-site storage of closure-related wastes (to the extent that they are restricted hazardous wastes) may be subject to time limits, which may pose a significant challenge since closure is likely to extend over a few years. For instance, PEO ACWA estimates that the closure of PCAPP will take 38 months (CDPHE, 2018, Attachment I). However, it may be possible to obtain agreement from federal or state regulatory authorities that the storage of closure-related wastes at BGCAPP and PCAPP meets the requirement of being stored for permissible purposes (i.e., to accumulate such quantities as necessary to facilitate proper recovery, treatment, or disposal). Alternatively, it may be possible to advocate for changes to applicable regulations or statutes to facilitate extended storage. For example, BGCAPP management previously advocated successfully for a statutory change that helped facilitate operations at the facility by establishing new waste codes for wastes produced from the chemical neutralization of chemical agent so that such wastes would no longer carry the waste codes for undiluted agent (BGCAPP, 2016).

Finding 19. It may be possible to obtain agreement from federal or state regulatory authorities that the storage of closure-related hazardous wastes at BGCAPP and PCAPP meets the requirement of being stored for permissible purposes (i.e., to accumulate such quantities as necessary to facilitate proper recovery, treatment, or disposal), such that the wastes could be stored longer than 1 year.

Recommendation 19. If it would enhance the efficiency of the closures of PCAPP and BGCAPP to store closure-related hazardous wastes for longer than one year, plant management should engage its state regulators to determine whether the existing regulations could be interpreted or modified to allow longer storage of these wastes.

TSCA

The BGCAPP stockpile contains M55 rockets loaded with nerve agent. These rockets are contained in shipping and firing tubes (SFTs) that contain PCBs in their fiberglass matrix. The PCBs in the SFTs caused legacy demilitarization facilities with M55 rockets, such as ANCDF, to be regulated under TSCA as well as RCRA and its state counterparts (Leidos, 2014). The current plan at BGCAPP is to ship SFTs uncontaminated with chemical agent off-site for disposal. Any SFTs contaminated with agent will have to be treated on-site, likely by thermal treatment in an SDC. Because of the presence of PCBs in the SFTs, any such treatment may trigger regulation of the process under TSCA and necessitate ultimate closure of the facility under that statute, as well as under the hazardous waste regulations as discussed above.⁷¹ Among other things, if treatment results in wastes or equipment being contaminated with PCBs, such materials would need to be decontaminated or disposed in accordance with applicable TSCA regulations as part of the facility closure.

⁶⁹ See 40 C.F.R. § 268.50; 6 CCR 1007-3 § 268.50; and 401 KAR 39:060 § 4.

⁷⁰ See 40 C.F.R. § 266.205(d)(2) and 401 KAR 39:090 § 6(4)(c).

⁷¹ See generally 40 C.F.R. Part 761 (TSCA regulations for PCBs).

Finding 20. Owing to the possible need for BGCAPP to treat agent-contaminated rocket SFTs that also contain polychlorinated biphenyls (PCBs), closure of the facility may be subject to TSCA as well as hazardous waste closure requirements, including the need to decontaminate or dispose of PCB-contaminated waste streams and equipment in accordance with applicable Toxic substances Control Act requirements.

Recommendation 20. BGCAPP management should study the extent to which the facility may become subject to Toxic substances Control Act closure requirements as a result of treatment of polychlorinated biphenyl-contaminated shipping and firing tubes, and modify the facility closure plans if necessary.

CONCLUSION

PEO ACWA has extensive experience gained from the successful closure of multiple legacy chemical demilitarization plants. It has a structure for approaching the upcoming PCAPP and BGCAPP closure activities and plans to use lessons learned from the closure of the legacy plants. Continued incorporation of lessons learned has been an enduring best practice of the entire, multisite, chemical demilitarization facility closure program.

The closure of PCAPP and BGCAPP represent the opportunity for PEO ACWA to “finish strong” while destroying the last of the legacy United States chemical weapon stockpile. The multi-decade history of this program (depicted in Table 1) has involved numerous challenging, yet successful, plant closures, building toward the closure of these final two plants. The committee has noted multiple best practices, both at legacy sites and at PCAPP and BGCAPP, such as

- Creating and maintaining a strong bottom-up safety culture that generates effective safety metrics and actively communicates safety metrics and all changes to relevant documentation to the workforce, resulting in good safety records;
- Incorporating lessons learned from previous site closures into the preliminary planning for PCAPP and BGCAPP closures;
- Building effective relationships between PEO ACWA and the contract labor forces, and
- Inviting early and frequent regulator engagement that encourages frequent regulator visits to the sites.

The committee has, in this report, made several recommendations for PEO ACWA as it prepares for the closure of PCAPP and BGCAPP. Many of the recommendations focus on the differences between PCAPP and BGCAPP and the legacy sites, such as

- PCAPP and BGCAPP are more complex plants, where agent is destroyed by chemical neutralization and secondary processing of the hydrolysate is performed;
- PCAPP and BGCAPP are the final sites to close in the entire stockpile destruction program, representing a new risk to labor continuity as there are no upcoming chemical demilitarization sites to move to;
- Through the multidecade closure process, PCAPP and BGCAPP are closing after the longest gap since a previous site closure;
- Colorado and Kentucky-specific hazardous waste regulatory requirements may require different waste storage and permitting strategies; and

- New and updated safety regulations have come into effect since the last site closure and may influence permitting and worker training activities—for example, OSHA standards 1926.1153 regarding silica exposure and 1926.62 regarding lead.

The committee believes that if the program continues following the identified best practices and follows the committee's recommendations, the closure of the last two plants and the closure of the entire chemical weapons stockpile disposal program can be accomplished safely and effectively.

Recommendations

General Recommendations

Recommendation 1. PEO ACWA should continue to use the lessons learned from previous closure activities to plan for the closure of PCAPP and BGCAPP. It should also use what will be learned when closing PCAPP to inform the eventual closure of BGCAPP.

Recommendation 2. BGCAPP and PCAPP plant staff should conduct an optimization study that balances the risks and benefits of various closure strategies, including an evaluation of interdependencies that exist in closing the various subsystems (e.g., technical requirements, labor availability, training needs, permitting issues, scheduling, physical boundaries, and environmental impacts).

Recommendations on Decontamination and Hazardous Wastes

Recommendation 3. PCAPP and BGCAPP staff should estimate the rate at which waste will be generated and the associated space, equipment, and personnel needed to package and ship the waste. It should also identify, and potentially construct, sufficient staging areas for waste handling and storage.

Recommendation 4. BGCAPP and PCAPP plant staff should conduct a planning study that evaluates the intended use of existing thermal treatment units for decontamination during closure operations, determine whether thermal treatment will be rate limiting to the overall closure process, and explore the possible expanded use of thermal treatment. This study should include an evaluation of treatment capacity, anticipated treatment rates and durations, size and geometric constraints, necessary permit revisions, and the possibility for occurrences such as agent being in unexpected places and the formation of residues. As part of the study, PCAPP and BGCAPP staff should identify all items that could be processed by thermal treatment, any disassembly necessary for larger equipment to fit into the thermal treatment units, and an estimate of throughput. PEO ACWA should also evaluate modifications to the environmental permits to enable the increased use of the thermal treatment units for decontamination of a broader range of contaminated materials and the overall impact of expanded thermal decontamination to the closure process.

Recommendation 5. Significant experience was gained in SDC decontamination conducted at ANCDF. PCAPP and BGCAPP plant staff should conduct a detailed study of the Anniston Chemical Agent Disposal Facility decontamination efforts and develop a decontamination approach that accounts for difficulties similar to those encountered previously.

Recommendation 6. PCAPP and BGCAPP staff should estimate the number of measurements that will be needed as a function of schedule and determine whether the lab, instrumentation, and personnel

resources will be capable of keeping up with the rate of waste generation. If not, the staff should investigate and identify mitigation strategies to prevent a slowdown in closure.

Recommendation 7. BGCAPP and PCAPP staff should continue to use unventilated monitoring testing for large pieces of equipment. It should also compare the efficiency of performing surface testing for small objects (e.g., less than 1 square foot surface area) compared to bulk unventilated monitoring, taking into account the full cycle time for clearing materials using each method (including the time to build and take down tents) and lab capacity.

Recommendations on Worker Safety and Industrial Hygiene

Recommendation 8. Program and plant management should continue to put safety first. This would include daily management involvement in safety including daily meetings to review work and any documentation changes, management participation in safety activities, requiring all staff to participate in safety activities, management review of all safety incident investigations and work pauses, and collaboration to ensure that safety metrics remain visible to managers and their respective workforces until completion of the project.

Recommendation 9. Plant management personnel should carefully estimate the extent to which equipment will be disassembled versus cut or sheared into pieces and the resulting impact on the labor required for disassembly and labor required for analytical characterization, as well as the safety impacts of different disassembly methods.

Recommendation 10. Program management should develop closure work packages. This should be done by a variety of staff (e.g., engineers, safety personnel, and operations staff). The work packages should:

- Ensure that decontamination and equipment disassembly are well thought out and that all tasks and associated hazards are accounted for;
- Include job hazards analyses, experiences and data from previous closures, and instructions from equipment vendors about how to best disassemble equipment;
- Include instructions for the safe cutting or shearing of equipment that cannot be disassembled;
- Provide clear instructions for when to pause or stop work;
- Be drafted on a schedule that anticipates delays in approvals and maintains a sufficient backlog of approved work packages to maintain workforce continuity; and
- Ensure that there is an adequate number of trained, experienced workers in order to avoid bottlenecks.

Recommendation 11. PEO ACWA should continue its effective relationship with contract labor, discuss the transition to closure activities. PEO ACWA and its contractors should consider programs that incentivize the workforce to stay through the completion of closure. These programs could include financial incentives or retraining programs that could make the workforce better able to obtain subsequent employment.

Recommendation 12. Program management should ensure that appropriate emergency response capability is always available onsite through the entire closure process. Actions such as regular emergency response training, training in the use of specialized equipment, and mock drills can help accomplish this. Such training should be conducted at least annually and whenever there are significant

changes in plant structure, equipment, or work procedures that significantly impact the safety environment.

Recommendation 13. When possible, program management should retain experienced workers to work on equipment with which they are familiar. It should be noted that some retraining may be necessary to refresh workers. Program management should also consider the use of specialized demolition contractors.

Recommendation 14. Program management should continue to carefully assess conditions during closure and continue enforcing strict adherence to PPE guidelines. Any relaxation of PPE requirements should not occur until data can be provided to support the change. Data from previous closures for similar PPE should be referenced to avoid surprises.

Recommendation 15a. During closure, plant management should ensure that health and safety hazards associated with materials, other than agent, receive adequate attention. Workers who will have potential exposures to silica and lead should receive appropriate medical monitoring, as laid out in the Occupational Safety and Health Administration regulations 29 CFR 1926.1153 and 1926.62, respectively. Attention should be given to ensure that appropriate personal protective equipment for these hazards is worn, even in areas that have been cleared of agent exposure.

Recommendation 15b. Plant safety personnel should monitor carbon monoxide, diesel exhaust, and oxygen levels in areas where equipment is being used, especially where there may be limited ventilation. Crews should be prepared to ventilate the area with auxiliary equipment and have evacuation plans in place.

Recommendation 16. Program management should provide appropriate annual ergonomic safety training to workers who have increased risk of injury due to their closure duties. Any special ergonomic considerations for a task should be addressed in the comprehensive work package for that task.

Recommendations on Environmental Safety, Regulations, and Permitting

Recommendation 17. When planning and executing closure, PCAPP and BGCAPP management should reach out to regulatory authorities early and on an ongoing basis, including encouraging site visits throughout the closure process.

Recommendation 18. PCAPP and BGCAPP plant management should make sure that plant closure is appropriately coordinated with closure and corrective action activities for the larger facilities on which are located.

Recommendation 19. If it would enhance the efficiency of the closures of PCAPP and BGCAPP to store closure-related hazardous wastes for longer than one year, plant management should engage its state regulators to determine whether the existing regulations could be interpreted or modified to allow longer storage of these wastes.

Recommendation 20. BGCAPP management should study the extent to which the facility may become subject to Toxic substances Control Act closure requirements as a result of treatment of polychlorinated biphenyl-contaminated shipping and firing tubes, and modify the facility closure plans if necessary.

Attachment A

Roster and Biographical Information

ROSTER OF THE COMMITTEE ON INITIAL CLOSURE PLANNING FOR THE BLUE GRASS AND PUEBLO CHEMICAL AGENT DESTRUCTION PILOT PLANTS

TIMOTHY J. SHEPODD, Sandia National Laboratories, Livermore, California, *Chair*
ROBIN COYNE, Spike Occupational Health & Safety, LLC, St. Charles, Illinois
AARON H. GOLDBERG, Beveridge & Diamond, P.C., Washington, D.C.
GARY S. GROENEWOLD, Idaho National Laboratory, Idaho Falls
DEBORAH L. GRUBBE, Operations and Safety Solutions, LLC, Chadds Ford, Pennsylvania
DAVID S. KOSSON, Vanderbilt University, Nashville, Tennessee
MURRAY GLENN LORD, The Dow Chemical Company, Freeport, Texas
STYRON N. POWERS, EHS-Process Safety Management (PSM) Risk Services, Palatine, Illinois
STANLEY I. SANDLER, NAE,⁷² University of Delaware, Newark

Staff

JAMES C. LANCASTER, Director, National Materials and Manufacturing Board
JAMES C. MYSKA, Program Officer, *Study Director*
AMISHA JINANDRA, Research Associate
JOSEPH PALMER, Senior Project Assistant

BIOGRAPHICAL INFORMATION

TIMOTHY J. SHEPODD, *Chair*, is the deputy director of the Mission Engineering Sciences organization at Sandia National Laboratories, in Livermore, California. Dr. Shepodd manages a line of approximately 50 scientists, engineers, software developers, and operations personnel in three groups, supporting numerous government sponsors. His group develops and deploys tools for national security. Previously, Dr. Shepodd managed chemistry and security-focused teams studying fundamental chemistry and materials science issues that supported high-rigor hardware for national security missions including the nuclear stockpile, chemical weapon demilitarization, solar energy materials, explosives chemistry, and corrosion in extreme environments. Dr. Shepodd has participated on the National Academies standing Committee on Chemical Demilitarization since 2013, as chair since 2018. In this role, he has witnessed the construction, containment philosophy, and operational evolution of the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) and Blue Grass BGCAPP Chemical Agent Destruction Pilot Plant (sites). He also served on the Committee on Assessment of Supercritical Water Oxidation System Testing for the Blue Grass Chemical Agent Destruction Pilot Plant from 2012-2013. Dr. Shepodd is a co-inventor and lead chemist for the Explosives Destruction System, the mobile destruction system used to batch-neutralize thousands of explosively configured chemical munitions both inside and outside the continental United States. He developed procedures, recipes, and analytical protocols with host sites to confirm the destruction of many chemical warfare agents. Dr. Shepodd also developed a prototype reactor for the batch- supercritical water oxidation (SCWO) of explosively configured chemical munitions and designed

⁷² Member, National Academy of Engineering.

and qualified air filters for the system's interface to the outside world. Dr. Sheppard received his B.S. in chemistry from the University of California, Los Angeles, and a Ph.D. in organic chemistry from the California Institute of Technology.

ROBIN COYNE is the principal of Spike Occupational Health & Safety, LLC, where she offers industrial hygiene and safety consulting services and training. Prior to Spike, Ms. Coyne was the director of health, safety, and environment for Central Garden & Pet, an innovator, marketer, and producer of quality branded products for consumer and professional use in the lawn and garden and pet supplies markets. She led a team of seven environmental health and safety (EHS) professionals that served as the primary EHS resource for over 50 Central Garden & Pet manufacturing and distribution facilities. Significant engineering projects spearheaded included addressing hazards associated with combustible dust operations and pesticide manufacture, resulting in mitigation of explosion hazards while doubling production capacity and nondetectable employee exposures to the active pesticide ingredient. Ms. Coyne also managed health and safety programs for RR Donnelley, Senior Flexonics, and G.D. Searle. Of note while managing the Searle industrial hygiene program, Ms. Coyne led hazard assessments of new products, processes, and capital projects, including establishment of exposure limits, sampling and analytic methods, and investigation of physical and environmental hazards, resulting in the proactive implementation of controls to mitigate hazards. Ms. Coyne is a certified industrial hygienist and a registered occupational hygienist (Canada). She earned a B.S. in biomedical engineering in 1977 from Northwestern University and an M.B.A. in 1987 from Roosevelt University.

AARON H. GOLDBERG is a principal of the law firm Beveridge & Diamond, P.C., where he focuses on U.S. and international regulatory requirements for managing hazardous wastes, transporting hazardous materials and dangerous goods, and ensuring that industrial chemicals are not diverted to use in making illicit drugs or chemical weapons. Mr. Goldberg's work includes helping companies determine whether they require hazardous waste facility permits under the Resource Conservation and Recovery Act, apply for such permits, appeal permit conditions, and comply with the terms of their permits. Mr. Goldberg previously worked as a consultant to the U.S. Environmental Protection Agency (EPA) and as a legal analyst in the White House Office of Management and Budget (OMB). He earned a bachelor's of science in chemistry, with high honors, from Yale University, as well as a master's of science in chemistry from the California Institute of Technology. Mr. Goldberg received his juris doctor degree from Stanford Law School.

GARY S. GROENEWOLD is a senior scientist in the Energy and Environment Directorate at the Idaho National Laboratory (INL), where he has conducted research in surface chemistry, gas-phase chemistry, and analytical measurement since 1991. Dr. Groenewold's research has focused on determining speciation and reactivity of radioactive and toxic metals (U, Np, Pu, Hg), and of toxic organic compounds (including VX, mustard, and sarin). He received a Ph.D. in chemistry from the University of Nebraska in 1983, where he studied ion molecule condensation and elimination reactions under the direction of Dr. Michael Gross. Dr. Groenewold has authored more than 130 research articles in these areas, has served on or chaired seven ad hoc committees on chemical demilitarization, and has both served on and chaired the standing Committee on Chemical Demilitarization. Dr. Groenewold has been appointed a National Associate of the National Academies of Sciences, Engineering, and Medicine.

DEBORAH L. GRUBBE is the owner and president of Operations and Safety Solutions, LLC. Previously, Ms. Grubbe was vice president of Safety Change Management at BP, where she was accountable to establish overall safety leadership and cultural improvement for five U.S. refineries. Prior to that, Ms. Grubbe was the vice president of Group Safety at BP in London, where she assessed, developed, and executed the group safety strategy. Ms. Grubbe graduated with a bachelor's of science in chemical engineering with highest distinction from Purdue University. She received a Winston Churchill Fellowship to attend Cambridge University in England, where she received a certificate of postgraduate

study in chemical engineering. She is a registered professional engineer in Delaware. Ms. Grubbe has been a member of several National Academies committees related to the demilitarization of chemical weapons, including work on the 2002 report, *Closure and Johnston Atoll Chemical Agent Disposal System Report*.

DAVID S. KOSSON is the Cornelius Vanderbilt Professor of Engineering and Professor of Civil and Environmental Engineering at Vanderbilt University, where he also has joint appointments as professor of chemical engineering and professor of earth and environmental sciences. Dr. Kosson earned his Ph.D. and M.S. in chemical and biochemical engineering and his B.S. in chemical engineering from Rutgers University. He also is principal investigator of the multiuniversity Consortium for Risk Evaluation with Stakeholder Participation (CRESP). Dr. Kosson's research focuses on management of nuclear and chemical wastes, including process development and contaminant mass transfer applied to groundwater, soil, sediment, and waste systems. His research also includes durability and performance assessment of cement and concrete systems in long-term environmental settings for nuclear and nonnuclear applications. Dr. Kosson's research in collaboration with the Energy Research Centre of The Netherlands on leaching of contaminants from wastes and construction materials and development of the leaching environmental assessment framework (LEAF) is currently providing the foundation for environmental regulation of these materials at U.S. Environmental Protection Agency (EPA), the Netherlands Ministry of Environment, and the European Union's Directorate General for the Environment. Dr. Kosson has served on and chaired committees of the National Academies focused on chemical weapons demilitarization for more than 20 years, including the Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program. Dr. Kosson has participated in or led many external technical reviews on nuclear waste processing for the Department of Energy (DOE) including for tank wastes and a range of technology approaches at Hanford, Savannah River, and Idaho sites.

MURRAY GLENN LORD is an associate global technology director in the Environmental Technology Center at Dow Chemical Company. Mr. Lord is responsible for technology development and technical support for Dow's Global Environmental Operations, which includes project areas in process optimization, technology development, and capital project execution. Mr. Lord has experience in project areas across multiple business and technology areas and has experience in starting up and operating industrial processes. He has served on four past chemical demilitarization committees, most recently on the Committee on Metrics for Successful Supercritical Water Oxidation System Operation at BGCAPP. Mr. Lord was also a member of the standing Committee on Chemical Demilitarization.

STYRON N. POWERS is a health, safety, security, and the environment (HSSE) senior consultant for EHS-Process Safety Management (PSM) Risk Services. Before that, Mr. Powers was vice president for environmental health safety and logistics security at US Foodservice. Prior to that, he was the director for HSSE at BP Refining and Marketing, Global Fuels Value Chain, and held senior HSSE positions at Invensys, RR Donnelly, and Lockheed Martin. He is a member of the board of directors of the Virginia Tech Department of Industrial and Systems Engineering. Mr. Powers was educated at Harvard's Advanced Management Program (2002); he holds an M.B.A. from Rutgers University and B.S. degrees in chemical engineering and biological life sciences from North Carolina State University. Mr. Powers is a certified safety engineer and certified hazardous materials manager.

STANLEY I. SANDLER is the Henry B. du Pont Chair Emeritus of the Department of Chemical and Biomolecular Engineering at the University of Delaware. He is also professor of chemistry and biochemistry. Dr. Sandler is the former director for the Center for Molecular and Engineering Thermodynamics and a professor of chemistry and biochemistry. His current research interests include applied thermodynamics and phase equilibrium, environmental engineering (the fate of chemicals in the environment, safety), computational quantum chemistry, computer-assisted engineering education, separations and purification (including of pharmaceuticals and proteins), computer-aided process design,

and statistical mechanics. Dr. Sandler has served on three prior ad hoc committees addressing the Pueblo and Blue Grass Chemical Agent Destruction Pilot Plants. He is the author of more than 400 refereed technical papers and is the author of 7 chemical engineering textbooks. Dr. Sandler earned his B.Ch.E. from the City College of New York and his Ph.D. in chemical engineering from the University of Minnesota.

Attachment B

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Attachment C

Acronyms

ABCDF	Aberdeen Chemical Agent Disposal Facility
ANCDF	Anniston Chemical Agent Disposal Facility
BGAD	Blue Grass Army Depot
BGCAPP	Blue Grass Chemical Agent Destruction Pilot Plant
CAA	Clean Air Act
CMA	Chemical Materials Activity (prior to July 2012, Chemical Materials Agency)
CWC	Chemical Weapons Convention
DRE	destruction or neutralization and removal efficiency
EPA	Environmental Protection Agency
GB	a nerve agent, also known as Sarin
GPL	general population limit
H	mustard agent, other designations include HD and HT
JACADS	Johnston Atoll Chemical Agent Disposal System
LDR	Land Disposal Restrictions
MPT	metal parts treater
MTU	munitions treatment unit
NECDF	Newport Chemical Agent Disposal Facility
NRC	National Research Council
OSHA	Occupational Safety and Health Administration
PBCDF	Pine Bluff Chemical Agent Disposal Facility
PCAPP	Pueblo Chemical Agent Destruction Pilot Plant
PCBs	polychlorinated biphenyls
PCD	Pueblo Chemical Depot
PEO ACWA	Program Executive Office for Assembled Chemical Weapons Alternatives
PPE	personal protective equipment
RCRA	Resource Conservation and Recovery Act
SCWO	supercritical water oxidation
SDC	static detonation chamber
SFT	shipping and firing tube

TSCA	Toxic Substances Control Act
TSDF	treatment, storage, and disposal facility
UMCDF	Umatilla Chemical Agent Disposal Facility
VSL	vapor screening level
VX	a nerve agent
WPL	worker population limit

Attachment D

Acknowledgment of Reviewers

This Consensus Study Report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies of Sciences, Engineering, and Medicine in making each published report as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We thank the following individuals for their review of this report:

Joan F. Brennecke, NAE,⁷³ The University of Texas at Austin,
Patrick D. Burton, Sandia National Laboratories,
Gail Charnley, HealthRisk Strategies, LLC,
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Thom J. Hodgson, NAE, North Carolina State University,
Carol Palmiotto, E.I. du Pont de Nemours & Company (retired),
Tanya Schnelzer, MPS North America, and
Marcia Williams, Nathan Associates.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations of this report nor did they see the final draft before its release. The review of this report was overseen by James C. Stevens, NAE, Stevens Solutions LLC. He was responsible for making certain that an independent examination of this report was carried out in accordance with the standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the authoring committee and the National Academies.

⁷³ Member, National Academy of Engineering.

⁷⁴ Member, National Academy of Sciences.

Attachment E

State-Specific Lists of Chemical Agents and Related Materials as Hazardous Wastes

TABLE E.1 Colorado and Kentucky Hazardous Waste Listings

Waste Code	Waste Description	Hazard Code ^a
Colorado Hazardous Waste Listings ^b		
K901	Waste chemical weapons using or containing any chemical compound identified in Appendix VII of Part 261 as the basis for this listing. Residues resulting from treatment of hazardous wastes with the codes P909, P910, and P911 are included in this listing.	R, H, T, C, E
K902	Any soil, water, debris, or containers contaminated through contact with waste chemical weapons listed as K901 or hazardous wastes listed as P909, P910, or P911.	R, H, T, C, E
K903	Hydrolysate: waste generated from the chemical neutralization of mustard agent by the addition of water and subsequent manipulation to a sustained and stable pH > 10 to ensure destruction of sulfonium ions and thidiglycol-mustard aggregates.	T, E
P909 ^c	bis(2-chloroethyl)sulfide. Chemical Abstracts Number: 505-60-2.	H
P910 ^c	Common names: Mustard, mustard agent, mustard gas, H, HD. bis(2-chloroethyl)sulfide and bis(2-chloroethylthio)ethyl ether. Chemical Abstracts Numbers: 505-60-2, 63918-89-8.	H
P911 ^c	Common names: Mustard, mustard agent, mustard gas, HT, mustard T. O-isopropyl methylphosphonofluoridate. Chemical Abstracts Number: 107-44-8. Common names: GB, Sarin.	H
Kentucky Hazardous Waste Listings ^d		
N001	GB (isopropyl methyl phosphonofluoridate) and related compounds.	H
N002	VX (O-ethyl-S-(2-diisopropyl-aminoethyl)-methyl phosphonothiolate) and related compounds.	H
N003	H (bis (2-chloroethyl) sulfide) and related compounds.	H
N101	Uncontaminated M67 rocket motor assembly, propellant component of the rocket motor, shipping firing tubes, and end-caps associated with GB munitions.	NS
N102	Uncontaminated M67 rocket motor assembly, propellant component of the rocket motor, shipping firing tubes, and end-caps associated with VX munitions.	NS
N201	Metal Parts Treater residue associated with GB munitions or related wastes.	NS
N202	Metal Parts Treater residue associated with VX munitions or related wastes.	NS

Waste Code	Waste Description	Hazard Code ^a
N203	Static Detonation Chamber residue and ash associated with H munitions.	NS
N301	Agent hydrolysate associated with GB munitions.	NS
N302	Agent hydrolysate associated with VX munitions.	NS
N401	Energetic hydrolysate associated with GB munitions.	NS
N402	Energetic hydrolysate associated with VX munitions.	NS
N501	Aluminum precipitate associated with treated GB wastes.	NS
N502	Aluminum precipitate associated with treated VX wastes.	NS
N601	Reverse osmosis reject or supercritical water oxidation effluent associated with treated GB wastes.	NS
N602	Reverse osmosis reject or supercritical water oxidation effluent associated with treated VX wastes.	NS
N701	Lab wastes associated with treated GB wastes and GB-containing lab wastes treated to destroy agent with caustic.	NS
N702	Lab wastes associated with treated VX wastes and VX-containing lab wastes treated to destroy agent with caustic.	NS
N703	Lab wastes associated with treated H wastes and H-containing lab wastes treated to destroy agent with caustic.	NS
N801	Off-gas treatment (OTM) condensate associated with treated GB wastes.	NS
N802	Off-gas treatment (OTM) condensate associated with treated VX wastes.	NS
N901	Spent decontamination solution associated with treated GB wastes.	NS
N902	Spent decontamination solution associated with treated VX wastes.	NS

^a C, corrosive; E, toxicity characteristic; H, acutely hazardous; I, ignitable; NS, not specified (presumably not acutely hazardous); R, reactive; T, toxic.

^b 6 CCR 1007-3 §§ 261.32 and 261.33(e).

^c Residues resulting from treatment of this waste are included in the K901 listing and do not carry this code. Soils, water, debris, or containers contaminated with this waste are included in the K902 listing and do not carry this code.

^d 401 KAR 39:060 § 3(4).